CEREAL CHEMISTRY

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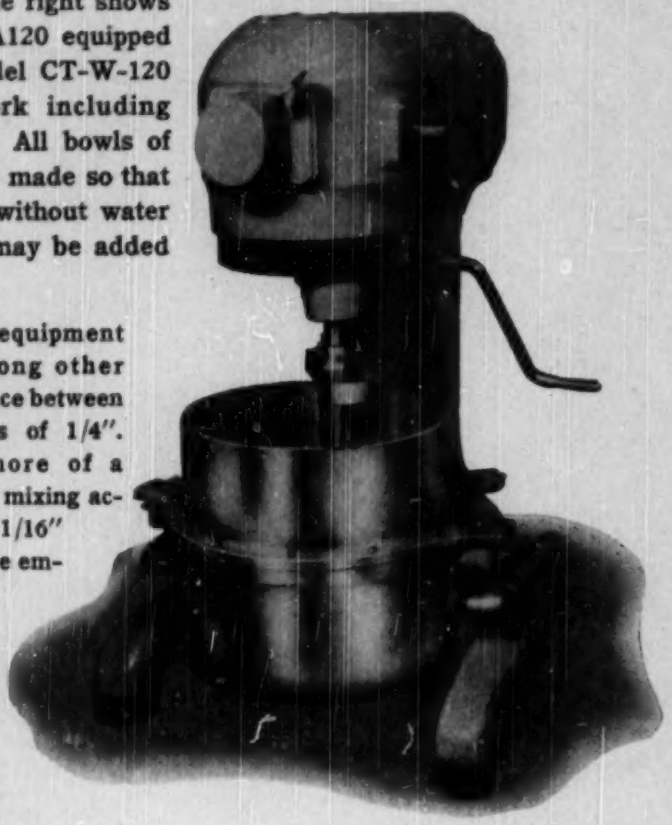

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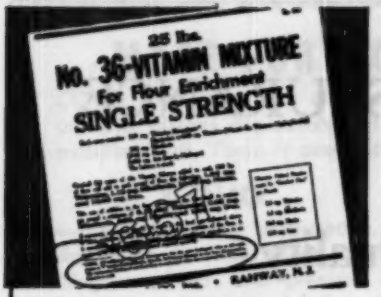

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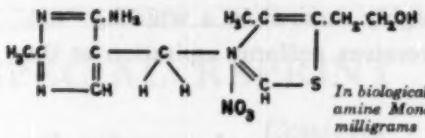

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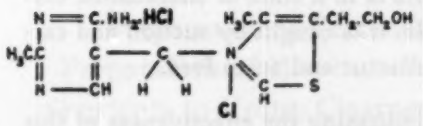

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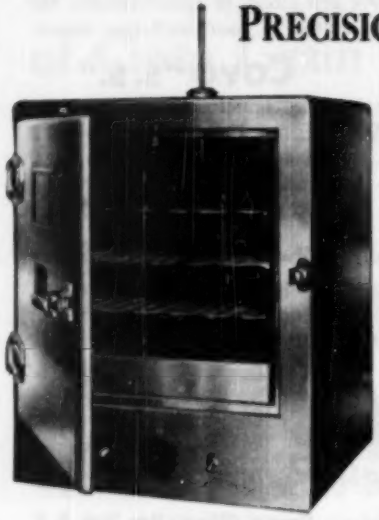

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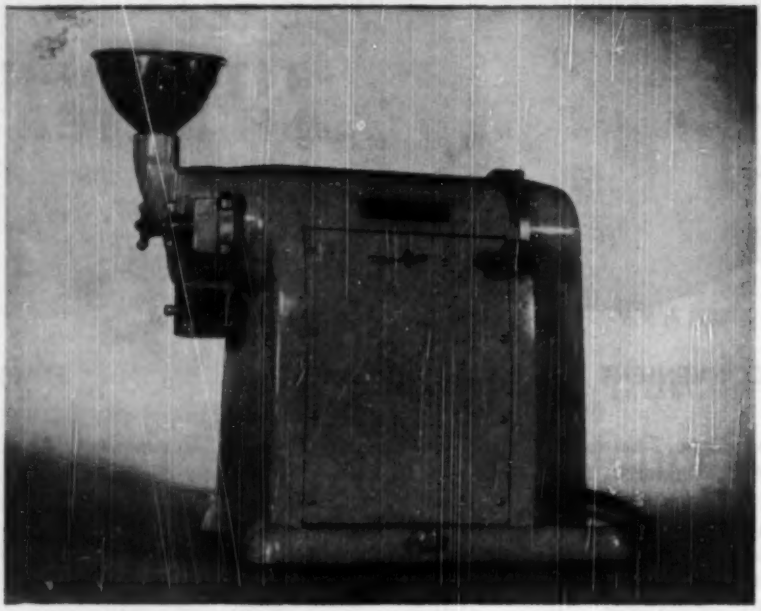

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CEREAL CHEMISTRY

VOL. XXVII JANUARY, 1950 NO. 1

THE EFFECT OF VARIOUS INGREDIENTS ON THE RATE OF FIRMING OF BREAD CRUMB IN THE PRESENCE OF POLYOXYETHYLENE (MONO) STEARATE AND GLYCERYL MONOSTEARATE[1]

E. C. EDELMANN, W. H. CATHCART, and C. B. BERQUIST[2]

ABSTRACT

Effective methods of retarding the progress of crumb firming during staling of bread include the use of lard as an ingredient, use of maximum water absorption coupled with minimum baking period required to produce bread with moisture content of not more than 38%, obtaining the maximum practical value for the ratio of baking pan volume to dough weight, and use of either polyoxyethylene (mono) stearate or glyceryl monostearate as an ingredient.

Non-fat dry milk solids, sucrose, yeast, and sodium chloride were found to have little effect in delaying the increase in crumb firmness.

The effect of various ingredients and of pan volume to dough weight relationship on increase in crumb firmness was investigated with and without polyoxyethylene (mono) stearate and with and without glyceryl monostearate.

Ever since scientific methods have been applied to the problems of the milling and baking industries, cereal chemists have striven to improve the keeping properties of bread. In the past, many investigators have reported the effect of various ingredients on certain manifestations of staling, such as increase in crumb firmness, reduction in crumb swelling power, reduction in the quantity of soluble starch, and other factors. Most of the work reported on this subject has been reviewed by Geddes and Bice (3).

In recent years, certain materials having surface-active properties and known as emulsifiers have come into use as inhibitors of crumb firming. The effect of various ingredients on increase in crumb firmness in the presence of the two most commonly employed surface-active agents; glyceryl monostearate and polyoxyethylene (mono) stearate, referred to in this paper as poems, has been studied.

[1] Manuscript received May 19, 1949.

[2] The Great Atlantic & Pacific Tea Co., National Bakery Division, New York 17, N. Y.

Materials and Methods

The effects on crumb firmness of the following levels of lard, non-fat dry milk solids, sucrose, yeast, sodium chloride, and water were investigated.

Lard	None, 3%, and 8%
Non-fat dry milk solids	None, 3%, and 6%
Sucrose	4%, 8%, and 12%
Yeast	1%, 2%, and 3%
Sodium chloride	None, 2%, and 3%
Water	60%, 64%, 65%, 66%, and 70%

All percentages of ingredients given in this paper are based on the flour weight as 100%. The effect of these ingredients on increase in crumb firmness and the effect of the relationship between the volume of the baking pan and the quantity of dough baked in it was studied with and without 0.5% poems and with and without 0.5% glyceryl monostearate. Whenever 0.5% glyceryl monostearate was used the absorption was increased 1%.

The bread was made in the laboratory by the sponge and dough process from a hard red winter wheat patent flour. All doughs had an absorption of 65% and contained 3% lard and 3% non-fat dry milk solids unless otherwise noted. Absorption was increased to 68% when 6% non-fat dry milk solids were added and was reduced to 62% when they were omitted. The absorption remained at 65% for all levels of lard, sucrose, yeast, and sodium chloride. Mixing was done with a Hobart Mixer, Model A-200, using a McDuffee type bowl and fork. Sponges had a temperature of 76°F. (24.4°C.) out of the mixer, and were fermented for 180 minutes at 80°F. (26.8°C). Doughs had a temperature of 80°F. (26.8°C.) out of the mixer and were divided immediately after mixing. The dough pieces remained at 80°F. (26.8°C.) for 20 minutes between dividing and molding. They were rounded by hand but molded mechanically. Two dough pieces, each weighing 9 ozs., unless otherwise noted, were placed crosswise in the baking pan to form one loaf. The baking pans used measured: inside top 8.5 in. by 4.5 in., inside bottom 7.5 in. by 3.5 in., depth 2.7 in., and had a volume of 87.9 cu. in. All doughs were proofed to the constant height of 9.1 cm. before baking. Baking was done in an electrically heated oven equipped with top and bottom heating elements and a rotating metal hearth. All bread was baked for 25 minutes at 450°F. (232°C.) unless otherwise noted. Each experiment, relating to a particular ingredient or factor being investigated, was done in duplicate, at least, and several were done in triplicate.

Changes in crumb firmness occurring during a period of 96 hours after baking were followed by organoleptic and compressimetric methods. All organoleptic tests were made by the same three labora-

tory workers. The softness of bread was determined by squeezing the loaf by hand, feeling the texture of the crumb, eating the bread, and mashing with the fist the cut surface of the loaf and noting its resiliency. Mechanical tests of crumb firmness were made with the Bloom

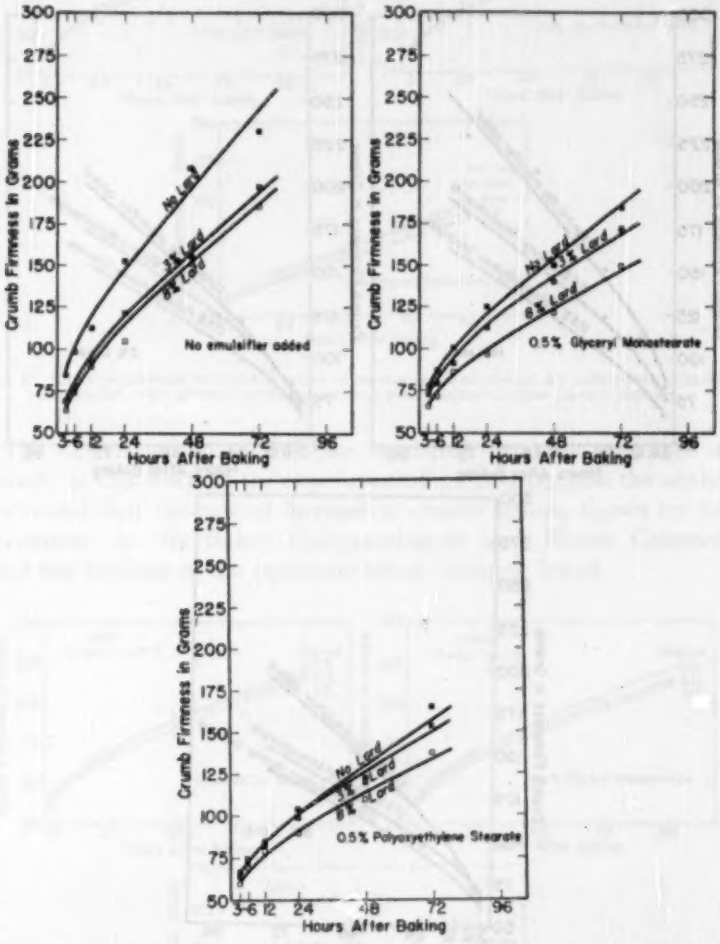

FIG. 1. Effect on increase in crumb firmness of various lard levels; without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

Gelometer equipped with a plunger of 1 in. diameter as described by Carlin, Hopper, and Thomas (2). In this work a constant strain of 4 mm. was used. Loaves were sliced in a commercial slicer 90 minutes after baking. Excluding both end slices, 17 slices each approximately 0.5 in. thick were obtained from a loaf. Two slices, placed together

on the platform of the Bloom Gelometer, were used for each compressibility measurement. Seven measurements were made on each loaf at each test period and average values were plotted to illustrate the changes in crumb firmness with time. Initial compressibility tests

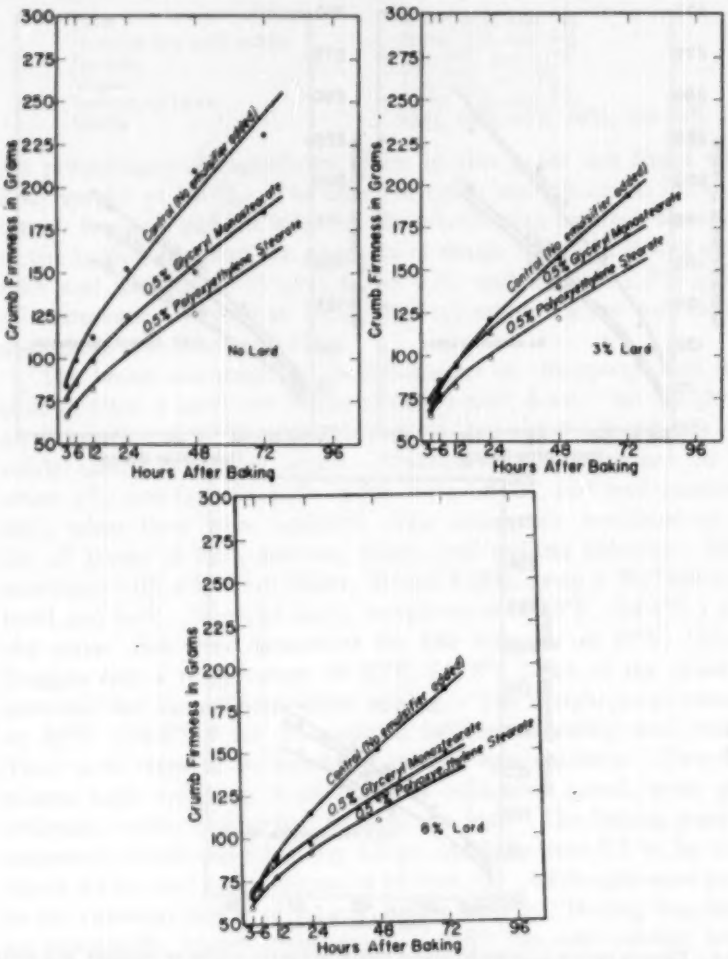

FIG. 2. Effect on increase in crumb firmness of glyceryl monostearate and of polyoxyethylene (mono) stearate at various lard levels.

were made as soon as possible; usually within three hours after baking. Further compressibility measurements were made on the same loaves at approximately 24, 48, 72, and 96 hours after baking. All loaves were stored at 80°F. (26.8°C.) between compressibility measurements.

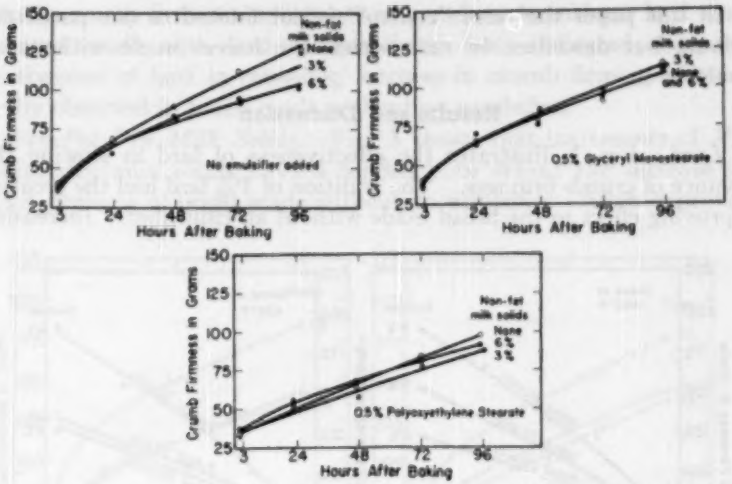

FIG. 3. Effect on increase in crumb firmness of various levels of non-fat dry milk solids; without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

The determination of increase in crumb firmness was used exclusively in this work as the experimental method because the authors have found that the rate of increase in crumb firming shown by such instruments as the Baker Compressimeter and Bloom Gelometer reflect the findings of the consumer when choosing bread.

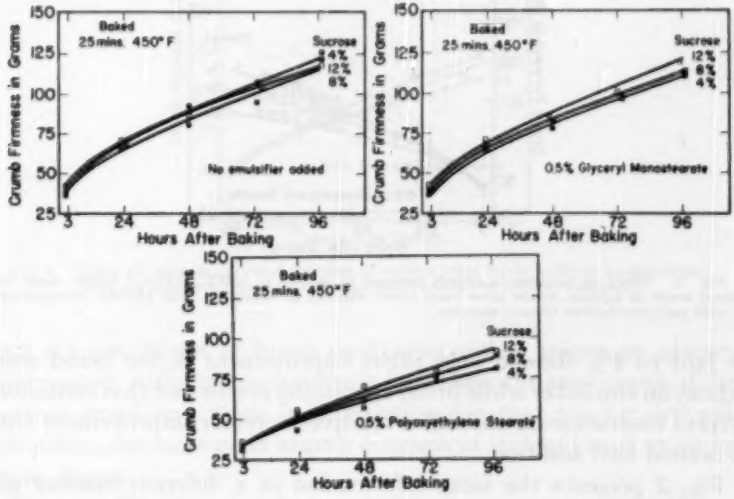

FIG. 4. Effect of various sucrose levels on increase in crumb firmness of bread baked 25 min. at 450°F. (232°C.); without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

In this paper the term "control" is not limited to one particular formula but describes, in each series, the loaves made without an emulsifier.

Results and Discussion

Lard. Fig. 1 illustrates the effectiveness of lard in slowing the advance of crumb firmness. The addition of 3% lard had the greatest improving effect in the bread made without an emulsifier. Increasing

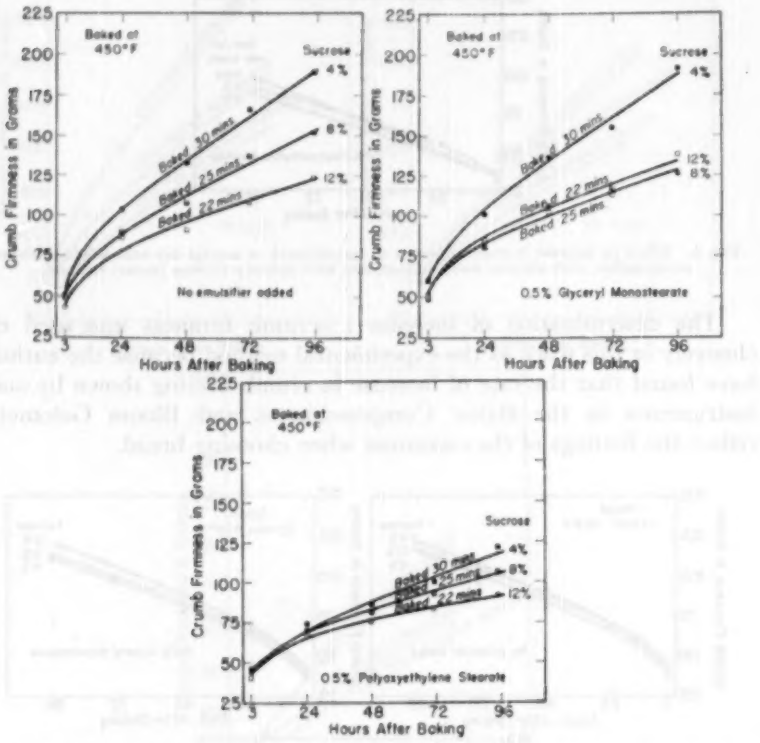

FIG. 5. Effect on increase in crumb firmness of baking at 450°F. (232°C.) bread, made with different levels of sucrose, to the same crust color; without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

the lard to 8% showed only slight improvement in the bread made without an emulsifier while bread containing poems and that containing glyceryl monostearate showed a relatively greater improvement from the second lard addition.

Fig. 2 presents the same information in a different manner and illustrates the effectiveness of poems and glyceryl monostearate at different lard levels. Poems and glyceryl monostearate are more

effective crumb firmness retardants in bread made without lard than in bread made with lard. Organoleptic tests indicated that the effectiveness of lard in retarding increase in crumb firming is more readily observed in bread made without an emulsifier.

Non-Fat Dry Milk Solids. Fig. 3 shows that increments of 3% non-fat dry milk solids have a tendency to retard the increase in crumb firmness of bread made without an emulsifier. Such improve-

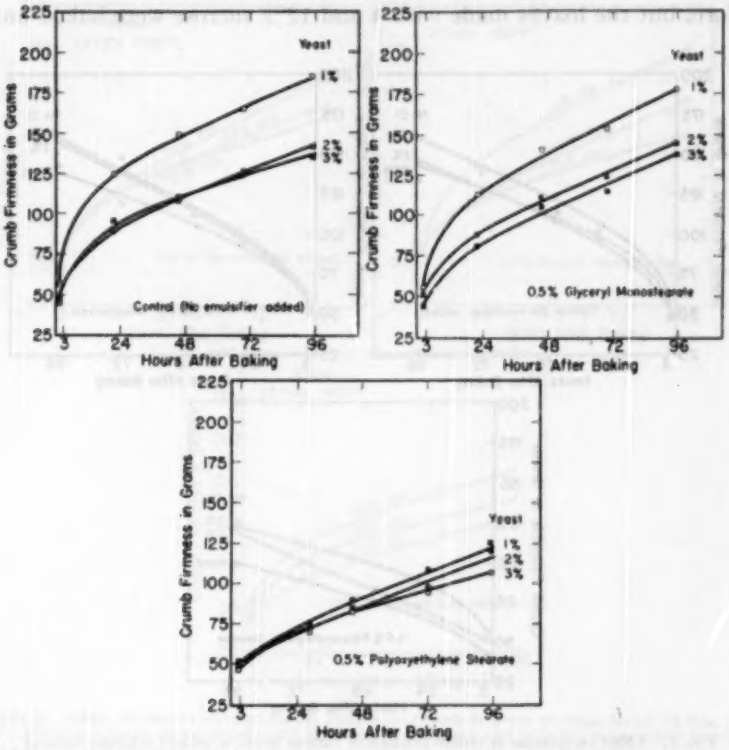

FIG. 6. Effect on increase in crumb firmness of various yeast levels; without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

ments are not shown in bread containing either poems or glyceryl monostearate. Although organoleptic tests show the same trend, differences are small and there is little indication that non-fat dry milk solids affect the increase in crumb firmness of staling bread to an important degree.

Sucrose. Fig. 4 shows that variations in sucrose content of from 4 to 12% have little effect on the degree or rate of change of crumb

firmness. In bread containing poems and glyceryl monostearate there is a slight tendency toward increased crumb firmness as the sucrose level is increased from 4 to 12%. Organoleptic tests indicated no differences in crumb firmness at various sucrose levels in bread containing poems but did indicate increased crumb firmness at 8 and 12% sucrose levels in bread made with glyceryl monostearate and in bread made without an emulsifier. Because of differences in crust color another experiment was made employing the same sucrose levels as before, but the loaves made with 4 and 12% sucrose were baked until

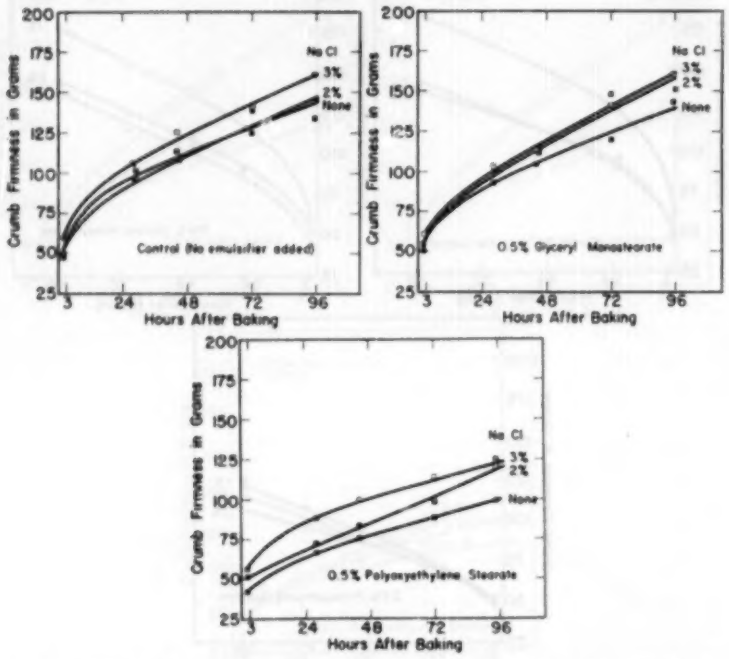

FIG. 7. Effect on increase in crumb firmness of various levels of sodium chloride; without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

the crust colors matched visually that of the loaf made with 8% sucrose and baked for 25 mins. Loaves containing 4% sucrose required 30 mins. and those containing 12% sucrose required 22 mins. baking time; all at 450°F. (232°C.). Results are illustrated in Fig. 5. In the second experiment there was a difference in the degree of increase of crumb firmness between loaves having different sucrose levels, especially in the control and glyceryl monostearate loaves. These results were confirmed by organoleptic tests. However, it is likely

that differences in baking time, not sucrose content, accounted for differences in the rate of increase in crumb firmness. The moisture content, as determined by the A.A.C.C. Method (1), of loaves baked for 22 mins. was below 38%.

Yeast. Fig. 6 shows that the use of 2% and 3% of yeast tends to produce softer bread than the use of 1% yeast. This effect was barely apparent in bread containing poems. Organoleptic tests confirmed

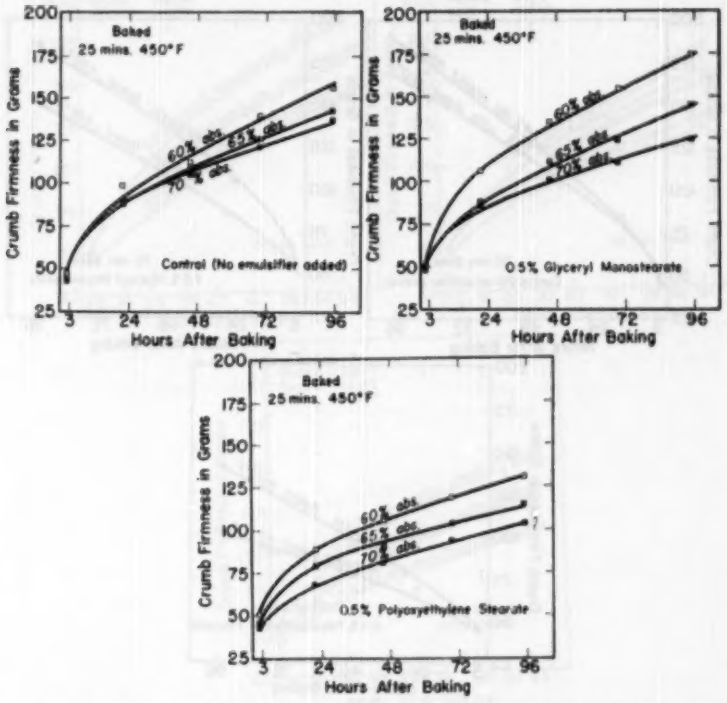

FIG. 8. Effect of various absorptions on increase in crumb firmness of bread baked 25 min. at 450°F. (232°C.); without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

these findings. Like all other doughs in this study, these were proofed to a constant height of 9.1 cm. Differences in increase of crumb firmness between loaves made with various quantities of yeast cannot be accounted for by differences in loaf volumes.

Yeast	*No emulsifier added*	*0.5% poems*	*0.5% glyceryl monostearate*
1%	2375 cc.	2475 cc.	2300 cc.
2%	2400 cc.	2450 cc.	2350 cc.
3%	2350 cc.	2575 cc.	2375 cc.

Because loaves containing 3% yeast had a strong odor 48 hours after baking, further investigation at higher yeast levels was not made.

Sodium Chloride. Fig. 7 shows that in all cases the crumb of bread made without sodium chloride was less firm than that containing 3% sodium chloride. However, this observation probably is without practical value and differences in increase in crumb firmness between loaves made with 2% and 3% sodium chloride were small. Organo-

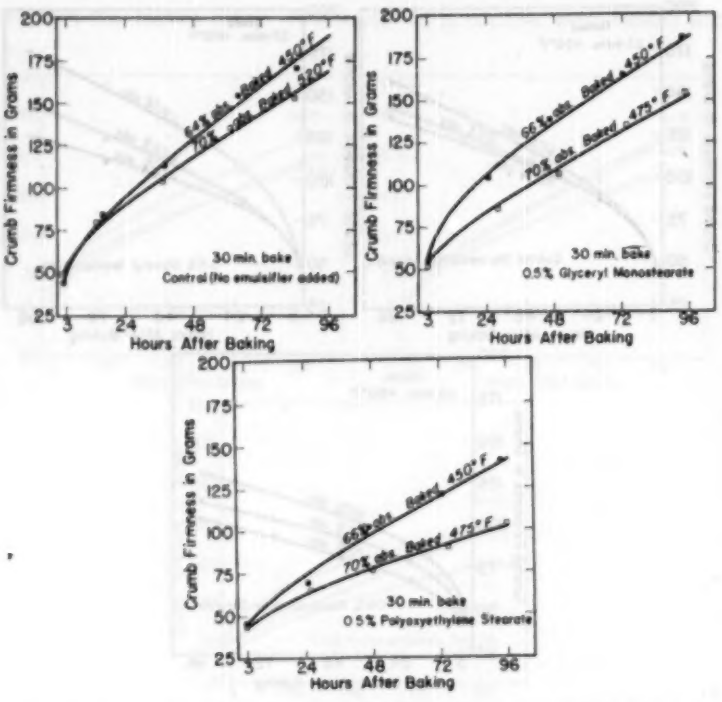

FIG. 9. Effect on increase in crumb firmness of bread baked for same period, but at different temperatures and absorptions; without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

leptic tests did not reflect differences between loaves made with the different levels of sodium chloride and it was noted that, in all cases, the loaves made without sodium chloride were approximately 12% greater in volume than those containing 3% sodium chloride.

Water. Two series of breads with absorptions ranging from 60% to 70% were made. Results from both series are illustrated in Figs. 8, 9, and 10. One series with absorptions of 60%, 65%, and 70% was baked for 25 mins. at 450°F. (232°C.). Fig. 8 shows that increased

absorption is effective in retarding the increase in crumb firmness especially in the presence of glyceryl monostearate or poems. Organoleptic tests confirmed this except in mastication where increased absorption brought no observable changes. A second absorption series (illustrated in Figs. 9 and 10) was made using absorptions of 64%

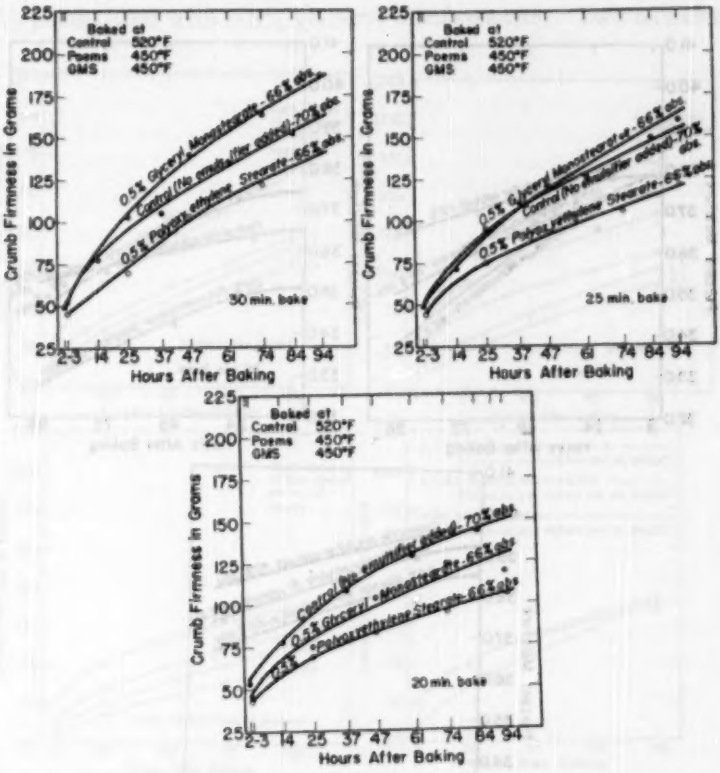

FIG. 10. Effect on increase in crumb firmness of bread baked for different periods, at different temperatures and absorptions; without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate.

and 70% for the control loaves and 66% and 70% for the poems and glyceryl monostearate loaves. Breads with absorptions of 64% and 66% were baked at 450°F. (232°C.); control bread with 70% absorption was baked at 520°F. (271°C.); and those containing poems and glyceryl monostearate and having an absorption of 70% were baked at 475°F. (246°C.). The doughs made with different levels of absorption were baked for three baking times, namely, 20, 25, and 30 minutes. Fig. 9 shows that the effectiveness of increased absorption in retarding the

increase in crumb firmness with time is maintained even when the bread is baked at a higher temperature. Although control bread baked at 475°F. (246°C.) was not available, that baked at as high a temperature as 520°F. (271°C.) was softer than glyceryl monostearate bread with an absorption of 66% and baked at 450°F. (232°C.). Fig. 10 shows that the crumb of control bread, with an absorption of 70% and

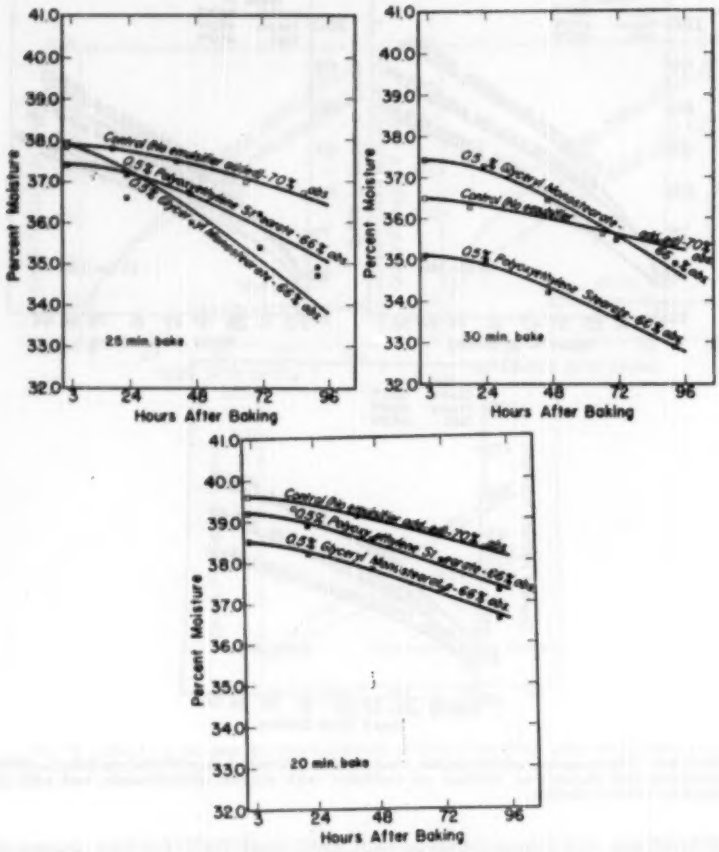

FIG. 11. Moisture content of bread illustrated in Fig. 10.

baked for 25 and 30 minutes at 520°F. (271°C.) is softer at the end of 96 hours than bread containing 0.5% glyceryl monostearate, baked for the same periods at 450°F. (232°C.), and having an absorption of 66%. This is not so when these same breads are baked for 20 mins. However, Fig. 11 shows that all breads baked for 20 mins. have a

moisture content (1) above 38% while those baked for 25 and 30 minutes are below 38%.

Relationship of Pan Volume to Dough Weight. It was of interest to investigate the effect of variations in the ratio of pan volume to dough weight on the rate of change in crumb firmness. As in the ingredient experiments, doughs were made without an emulsifier, with 0.5% poems, and with 0.5% glyceryl monostearate. Two fermented

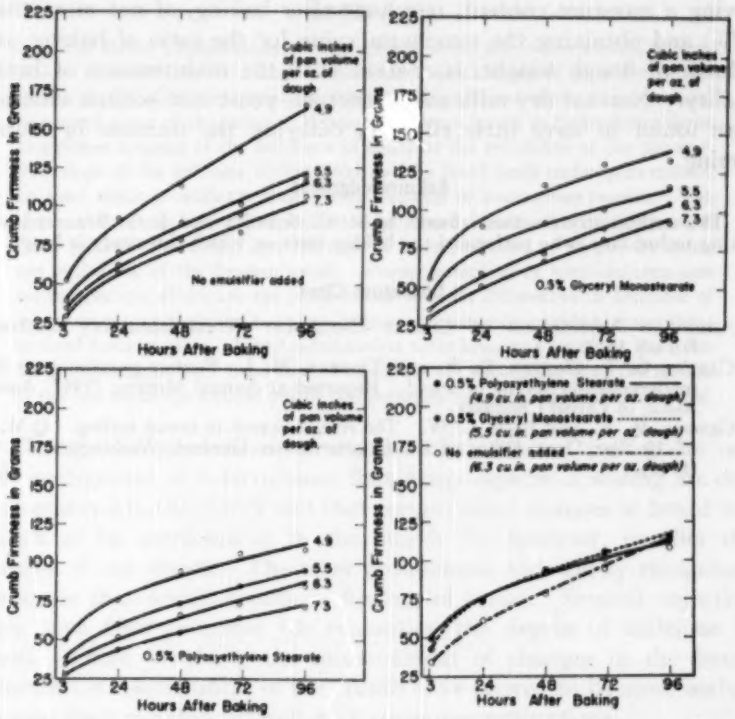
Crumb Firmness in Grams
Hours After Baking
Cubic inches of pan volume per oz. of dough
4.9
5.5
6.3
7.3
No emulsifier added
0.5% Glyceryl Monostearate
0.5% Polyoxyethylene Stearate
(4.9 cu. in. pan volume per oz. dough)
(5.5 cu in. pan volume per oz. dough)
(6.3 cu in. pan volume per oz. dough)

FIG. 12. Effect on increase in crumb firmness of relationship between pan volume and dough weight; without an emulsifier, with glyceryl monostearate, and with polyoxyethylene (mono) stearate. Also the effect of various pan volume—dough weight factors, singly and in conjunction with glyceryl monostearate or polyoxyethylene (mono) stearate.

dough pieces, each pair having a total weight of 18, 16, 14, and 12 ozs., were baked in pans having a volume of 87.9 cubic inches giving 4.9, 5.5, 6.3, and 7.3 cubic inches of pan volume per oz. of dough, respectively. Fig. 12 shows that the rate of increase in crumb firmness, over the entire range, was decreased as the number of cubic inches of pan volume per ounce of dough was increased. Fig. 12 also shows that bread made without an emulsifier and having 6.3 cu. in. of pan volume

per oz. of dough was as soft during a 96 hour period as bread containing 0.5% poems and having 4.9 cubic inches of pan volume per oz. of dough; and also as soft as bread containing 0.5% glyceryl monostearate and having 5.5 cubic inches of pan volume per oz. of dough.

The results of this study indicate factors effective in delaying the advance of crumb firmness are: the use of either poems or glyceryl monostearate; the use of lard as an ingredient; the maximum absorption coupled with the minimum baking period required to yield bread having a moisture content, one hour after baking, of not more than 38%; and obtaining the maximum value for the ratio of baking pan volume of dough weight, consistent with the maintenance of bread quality. Non-fat dry milk solids, sucrose, yeast and sodium chloride were found to have little effect in delaying the increase in crumb firming.

Acknowledgment

The authors express their thanks to R. G. Schmidt and J. G. Braunreuther, baking technicians, who performed the baking tests on which this study is based.

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A STUDY OF THE EFFECTS OF VARIOUS TECHNIQUES ON THE MEASUREMENT OF THE FIRMNESS OF BREAD BY THE BAKER COMPRESSIMETER [1]

L. B. CROSSLAND and H. H. FAVOR [2]

ABSTRACT

The Baker Compressimeter was used to study the force-deformation relations in bread crumb. Large variations in thicknesses of prisms of bread crumb do not alter these relations when the dimensions of the plunger equal or exceed those of the prism. Whole slices were found to be undesirable as test pieces because of the influence of shear at the perimeter of the plunger. The slope of the softness curves produced by fixed force techniques cannot be used alone to indicate staling rate because of anomalous results. The slope of firmness curves, as indicated by fixed deformation techniques, is fairly constant, as bread ages beyond 12 hours; so tests at 18 and 66 hours are indicative of the firming trend. Proper sampling in fixed deformation techniques can eliminate the influence of random differences in firmness of loaves on rates of firming, but these influences cannot be avoided by sampling in fixed force studies. Fixed deformation technique was found to have definite advantages over fixed force technique. It was found that the results of the two techniques could not be compared by the simple use of reciprocals.

Though the mechanism or mechanisms of bread staling are not fully understood, it is recognized that many aspects of staling are due to alterations in the starch and that certain other changes in bread not known to be attributable to the starch do, however, parallel the changes of the starch. The most pronounced and widely recognized change is that which results in firming of bread. Several objective tests have been proposed for evaluating the degree of staleness of bread. Those involving the measurement of changes in the force-deformation relationships of the crumb have proven to be most useful, because they correlate so well with consumer evaluations.

With few exceptions, these force-deformation studies have been made using a machine of the type described by Platt (4) or the Baker Compressimeter (5) which is essentially only an improvement on the Platt machine. No two investigators have used the same test conditions. Some operators have tested whole slices of bread, others, only sections of crumb. Some have recorded values for force for a fixed deformation; others have reported deformation for a fixed force. There has been considerable variation in the maximum values of force and deformation in such studies.

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Geddes and Bice (3) completely reviewed the literature on bread staling and recommended that methods of evaluating staleness be standardized, so that results of various investigators might be compared.

The object of this study was to determine the effects of various fixed conditions on the values obtained by the compressimeter method for determining the staleness of bread, and to establish an optimum set of conditions and procedures which will reflect the changes that occur in bread as it ages.

Experimental

The Baker Compressimeter equipped with a plunger 32 mm. square attached at the position nearest the fulcrum was used in all test work, except as noted.

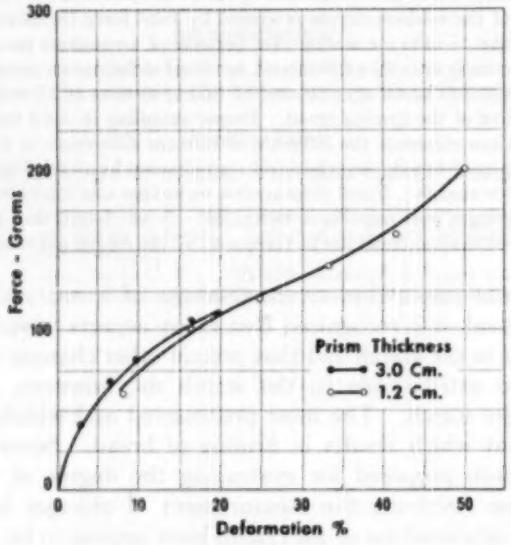

Fig. 1. Effect of prism thickness on the profile of the force-deformation curve of bread crumb.

The bread used in these tests was made from an average commercial formula by the sponge-dough process explained by Favor and Johnston (2) and was stored at 86°F. during the test period, except as noted.

Effect of Thickness of Test Prism. Rectangular prisms of 18-hour-old bread 32 mm. square, both 12 mm. and 30 mm. thick, were tested in the Baker Compressimeter by taking readings of force at 1 mm. intervals, as the drum rotated.

When force was plotted against per cent deformation (Fig. 1), it was found that overlapping portions of the curves were quite similar, indicating that large variations in slice thickness did not alter the

nature of force-deformation curves. Platt & Powers (5) noted the advantages of using slices of commercial thickness. Inasmuch as thickness of the test prism is here indicated to have little qualitative effect on results, a thickness of 12 mm. was used in subsequent tests. A prism of these dimensions (32 mm. square by 12 mm. thick) is referred to as a standard prism.

Effect of Age on Stress-Strain Relations in Bread Crumb. Force-deformation curves of bread at 4, 18, 42, 66 and 90 hours of age were obtained by plotting forces required to compress a standard prism 1 to 6 mm.

It will be noted in Fig. 2 that the profile of the curve changes very little with age, though the crumb is indicated to be progressively

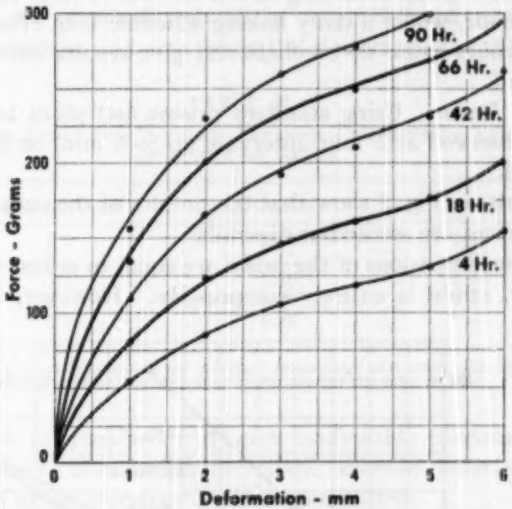

Fig. 2. The influence of aging on the profile of the force-deformation curve for bread crumb.

firmer at any deformation. It is interesting that in this family of curves the slopes are a minimum between 3 and 4 mm. deformation in each case (Table I). It is likely that the high force required to produce the 1st mm. deformation is due to the arch type cell structure. As the cells become deformed, the force required for additional deformation decreases, until the bread loses its characteristic texture and approaches a continuous mass.

Obviously, in a practical test, it is not possible to make tests every few hours. The changes occurring in bread during the period from 12 to 72 hours are most interesting to the consumer since this is the period during which most bread is eaten. However, 12 and 72 hour tests are

TABLE I

SLOPE OF FORCE-DEFORMATION CURVES OF BREAD AT VARIOUS AGES

Force at..... Minus force at.....	1 0	2 1	3 2	4 3	5 4	6 mm. 5 mm.
Age in hours						
4	54*	31	21	13	13	22
18	81	42	23	15	15	24
42	109	56	27	17	22	31
66	134	67	28	19	21	27
90	156	74	29	19	22	—

* Grams per differential millimeter compression (Fig. 2).

highly inconvenient when the bread is laboratory baked. The 12 hour test is due after normal working hours, and the 72 hour test is due at a conflicting hour, where a daily baking schedule is in effect. Tests at 18 and 66 hours cause no conflicts and give results indicative of the firming trend.

Slice vs. Prism. Using standard prisms and slices 12 mm. thick, force was observed at 1 mm. intervals up to 6 mm. on bread 18 and 66 hours old.

The results in Fig. 3 show that the profiles of the curves for prisms and whole slices are somewhat dissimilar.

When the dimensions of the prism are equal to or less than those of the plunger, strain is entirely compressive. However, in the whole

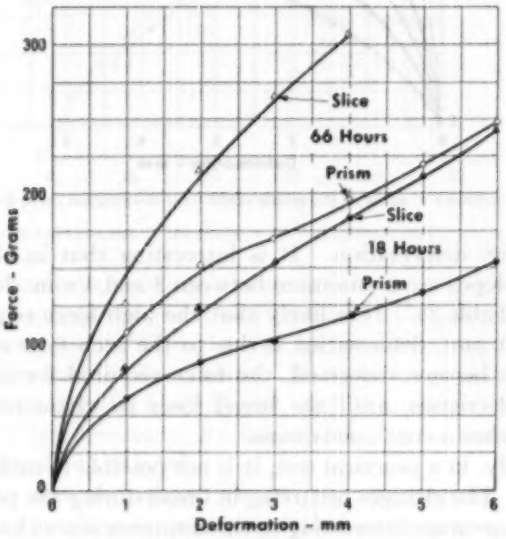

Fig. 3. Contrasting profiles of force-deformation curves for slices and prisms of bread crumb.

slice there is resistance offered to the plunger by the crumb at the perimeter which is in shear. The plunger produces a cup shaped depression in a whole slice, and when the plunger is released, after a high deformation, the outline of the plunger remains well defined indicating more pressure exerted at the perimeter than under the face of the plunger.

In tests of prisms and whole slices of a given type of bread, both 12 mm. thick, a fixed relation existed between forces required for a given deformation of a slice and prism. This relation was relatively constant as the bread aged, tending to confirm the observation of others that testing of whole slices under a given plunger is equivalent to increasing prism and plunger area; however, this ratio of forces was a function of the extent of deformation (Table II).

Forces required to compress a prism of crumb and a slice comparable amounts are obviously related in a complex manner which involves plunger shape, and area, extent of deformation, and, probably,

TABLE II

RELATIVE EFFECTIVE PLUNGER AREAS IN COMPRESSION TESTING OF SLICES OF BREAD

Deformation in mm.	1st Day	3rd Day
1	1.34*	1.27
2	1.43	1.42
3	1.45	1.55
4	1.55	1.55
5	1.59	—

* Calculated as grams force required for indicated deformation of a whole slice divided by grams force required to compress a prism the same area as the plunger the same amount.

tensile strength of crumb. It appears inadvisable to measure values influenced by more than one characteristic of bread, when comparison with results of other investigators is contemplated.

Fixed Deformation vs. Fixed Force. The data in force-deformation studies have been presented graphically in two different manners. One of the most widely used means of presenting the data has been as compressibility or so-called softness curves, which are of hyperbolic type, so there is no curve parameter which may be used to illustrate staling rate. Recently, the trend among investigators has been to plot data as firmness against time; this produces a line with a characteristic slope.

As bread ages beyond the first 12 hours of rapid change, firmness is nearly a straight line function of time. Only two points are required to plot such a curve, whereas a large number are required to plot a curve of hyperbolic type. Because the differences in firmness between loaves of the same batch of bread are often greater than the differences

in firmness of the two halves of a loaf, it is preferable to test half of each loaf under observation at each time interval. In this way, the influence of random differences in firmness of loaves is minimized, and differences in firmness at different test times are attributable to aging. To obtain points required to plot the hyperbolic type curves, different loaves must be used at each time interval because the loaves cannot be symmetrically divided into more than two portions for compression tests. Readings at different times, therefore, are influenced by random differences in firmness of loaves, as well as by aging of the bread.

Fixed force studies were made by reading deformation at fixed force values while the machine was in operation, in contrast to taking

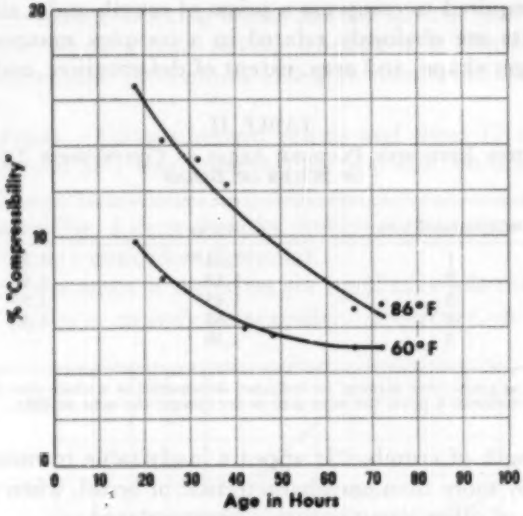

Fig. 4. The influence of storage temperature on "slope of the compressibility curve" for bread crumb under a fixed stress of 11.7 gms/cm².

equilibrium values. The nature of the curves was similar, although higher forces were required for a given deformation when force was read with the machine running.

Bread stored at 86°F. was tested and the values plotted as "compressibility" as is customary in fixed force studies. As indicated in Fig. 4 the curve is flatter for bread stored at 60°F. than for that stored at 86°F. The "slope" of such curves has been used alone as an index of staling rate. From these curves, then, it would appear that bread stored at 60°F. stales less rapidly than bread stored at 86°F., a conclusion which is in conflict with the observations of all who have studied the influence of temperature on bread staling. If the fact that soft-

nesses at the earliest test are not equal is considered, the evaluation becomes complicated and the manner in which allowance should be made is unknown.

Fixed Strain. Standard prisms tested at 4 to 90 hours at fixed deformations give curves shown in Fig. 5. Though the firmness values vary as the deformation, the slopes during the period from 12 to 90 hours are roughly equal for deformations from 2 to 4 mm. It would appear, therefore, that the slope of firmness-age curves is a parameter characteristic of the material tested and is not affected by moderate

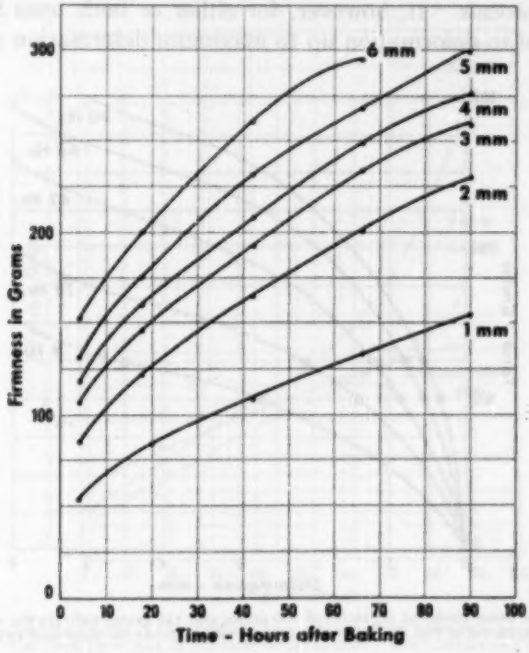

Fig. 5. The influence of deformation on the time-firmness relations in bread crumb.

changes in technique with respect to per cent deformation, provided that per cent deformation is fixed for the duration of the test.

Additional techniques suggested in *Cereal Laboratory Methods*, such as the one where the force on the prism is maintained at constant value and the deformation at definite time intervals is observed (1), have been briefly studied and found to be time consuming and of little, if any, merit, chiefly because curves rather than point values are obtained at each test time. The curves can be interpreted only with difficulty, if at all.

Of the techniques studied, the fixed deformation procedure was judged to have advantages far greater than any noted for fixed force technique.

Attempts have been made by some investigators to compare data obtained by fixed deformation studies with those obtained under fixed force conditions. This has been done by plotting both as firmness or as "compressibility." To do this, the reciprocal values of the appropriate set of data are obtained. If, under the conditions of both tests, force were proportional to deformation in the control breads, at all respective test times, it would be possible to make comparisons by use of reciprocals. If, however, for either or both tests force is not proportional to deformation up to maximum deformation at each test

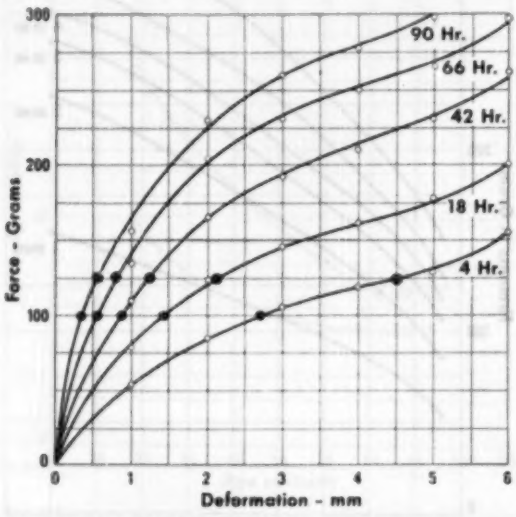

Fig. 6. The dense circles at ordinates of 100 grams and 125 grams indicate the data used in producing the broken curves of Fig. 7. The ordinates at 1 mm. indicate the data used to produce the solid curve of Fig. 7.

time, the use of reciprocals is not justified, so such comparisons cannot be made.

Using fixed force data to obtain firmness type curves, the possibly misleading results of such comparisons may be illustrated. The data used are indicated by the large dots on the family of curves of Fig. 6. By dividing the fixed force value in grams by the deformation in mm. a quantity is obtained, the dimensions of which are grams/mm., the same as for firmness readings.

Firmness type curves based on those data are indicated by broken lines and, obviously, do not correspond in profile to the curve produced

by the fixed strain technique, as represented by the solid curve. As the data represent one sample of bread and the curves indicate three differing rates of change of firmness, it is evident that data obtained by fixed force technique cannot be compared with those obtained by fixed deformation methods by the simple use of reciprocals. It is further indicated that small changes in fixed force value alter the nature of the resulting curves appreciably.

In tests of crumb at 18 and 66 hours, it is desirable that a deformation be used which will indicate a maximum change of required force over the test period. Fig. 8 represents the firmness of bread crumb

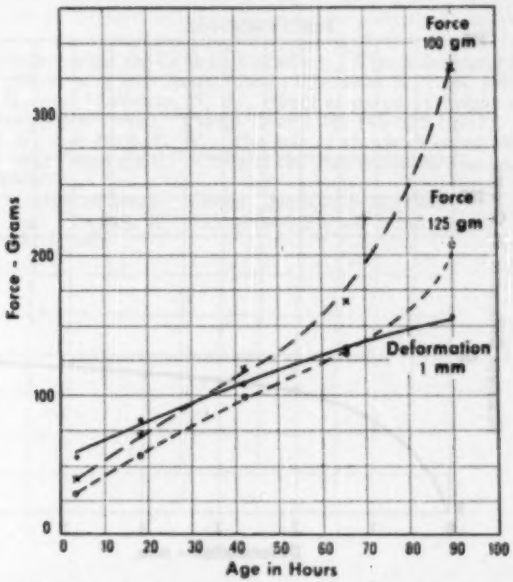

Fig. 7. Contrasting profiles of time-firmness curves obtained by fixed deformation technique and those calculated from fixed force data on the same bread sample. The captions on the curves indicate the fixed condition under which the data were obtained.

prisms at 66 hours minus the firmness at 18 hours at deformations up to 6 mm.

Up to a deformation of 1.5 mm., the slope of the curve is quite high. Evidently slight variations in strain value at which force is read would cause considerable fluctuations in the results. As the Baker machine is normally read while running, it appears inadvisable to take readings at less than 1.5 mm. It will be noted that the difference increases very little for deformations over 3 mm. There is no readily apparent way of selecting any particular value over 1.5 mm. that would be more valid than another. However, the use of lower deformations allows a

study of products over longer intervals of time because off-scale values are produced at a later time. Based on these considerations, a deformation of 2.5 mm. was selected as optimum.

Suggested Method for Determination of Staling Rate of Bread with the Baker Compressimeter. Select two or more loaves of comparable volumes from each batch to be tested. Wrap in moisture-proof paper and store at 86°F. At 18 hours from the oven, using commercial slice or 12 mm. slices, cut prisms to the dimensions of the plunger (32 mm. square). The prism should be taken at about 1 inch from the lower crust and the side away from the "break." Use half of each loaf, discarding those prisms with large holes or hard cores. The two end

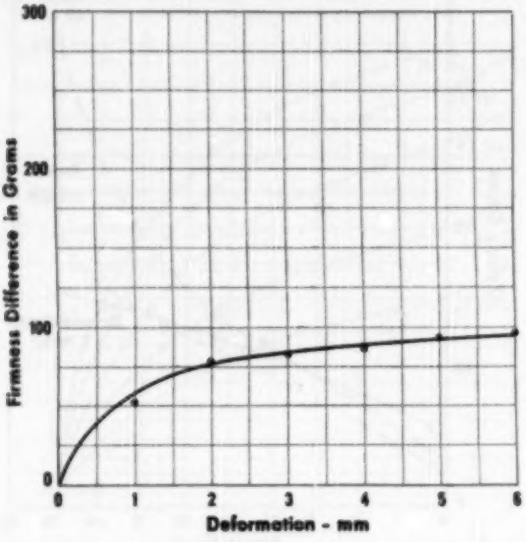

Fig. 8. The influence of deformation on the firmness-difference of bread crumb 66 and 18 hours old.

slices should be used to cap the open end of the loaf before rewrapping and returning to storage.

With the plunger at position 1, place the test prism beneath the plunger and turn Nut B (1) to adjust the pointers to zero. Start the motor and when the test piece has been compressed 2.5 mm., read scale J and multiply by the leverage. Average all readings for the batch.

At 66 hours from the oven, test the remaining halves in the same manner. The difference between the 3rd and 1st day averages is an index of the staling rate of the batch.

Correlation of Test Method with Consumer Evaluations. To determine whether the values measured by such a test would correlate with

consumer evaluations of firmness, bread 1, 2, and 3 days old was tested for firmness, as described, and, then, slices of each were offered to a panel of 20 people. Each was asked, "Which is most firm?" and then, "Which of the two others is less firm?"

Of the 20 people, 18 judged the 3 day old bread with a firmness reading of 195 grams as most firm and 18 judged the 1 day old bread with a reading of 105 grams as least firm. The two day old bread gave a reading of 131 grams.

These results show that the measurement of firmness by the Baker Compressimeter, using the selected test conditions, correlates with normal consumer evaluation of firmness.

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CHANGES IN THE RATE OF FIRMNESS DEVELOPMENT IN BREAD AT DIFFERENT SEASONS AND WITH THE USE OF EMULSIFIERS [1]

OSCAR SKOVHOLT and R. L. DOWDLE [2]

ABSTRACT

Compressibility determinations indicated that emulsifiers reduce the rate at which bread increases in firmness with age and that polyoxyethylene stearate is more effective than a vegetable oil monoglyceride in this respect. Measurements made during different seasons of the year showed that bread became firm more quickly in temperatures such as prevail indoors during winter as compared with those encountered during the warmer months of summer.

A controversy exists as to whether some of the recently developed emulsifiers are in effect merely bread softeners or whether they retard the rate of firmness development. The term "staling" might be applied to the latter change since it is believed that this phenomenon is chiefly characterized by increasing firmness and harshness when eaten or when judged by some type of squeeze test. Much work remains to be done in defining the process of staling. Until such a complete definition is available, controversy can be avoided by referring to the observed changes in firmness with age rather than to antistaling properties.

The purpose of this investigation was to determine the effect of two different types of emulsifiers on the rate of firmness development in bread. There was no change in the absorption used since extra water tends to increase the initial softness. Loaf volumes were approximately the same throughout the investigation. Variation in volume can also be an important factor in variable initial softness. The amount of bake also influences initial softness and this factor was kept constant throughout the investigation. An effect of temperature upon rate of firmness development became evident while making these compressibility measurements throughout the year. Some average values were obtained for the rate of firmness development during different seasons of the year.

Materials and Methods

In order to conform to commercial baking practice, a sponge and dough method with average commercial formula was employed. This

[1] Presented at the annual meeting—May, 1949. Manuscript received, June 13, 1949.
[2] From the laboratories of Quality Bakers of America Cooperative, Inc., N. Y., N. Y.

included the use of 3% shortening in the control doughs and 2% when using an emulsifier. Loaves were produced in pans with dimensions of 4 × 8 × 2½ in. and with doughs scaled at 430 g. Time and temperature factors for all steps in production were in line with accepted commercial practice. A baking time of 24 min. at 230°C. produced a more thorough bake than is evident in much commercial bread at the present time.

Two types of flour were used throughout the investigation but with a different sample for each set of baking tests. The flours used were average bakers southwestern hard winter and hard spring wheat types of medium extraction. Each set of loaves compared for firmness was made with either the same flour or a blend of similar samples.

Bread firmness was determined by the Baker Compressimeter using the optional method of constant strain as mentioned in Cereal Laboratory Methods (1). Readings were taken of the load required for depressions of 2, 3, 4 and 5 mm. These readings were made on at least six slices from each loaf tested.

Loaves were wrapped in ordinary waxed paper as soon as sufficiently cooled. They were then held in a cabinet and were subject to the usual variations in temperature until they were used for compressibility tests.

Two types of emulsifiers were used in the series specifically set up to study the rate of firmness development. They were a polyoxyethylene stearate and a vegetable oil monoglyceride and both were used at a level of 0.5% of flour weight. The latter had a somewhat lower melting point (46°C.) than most ingredients first offered the bakers as glyceryl monostearate.

Results and Discussion

Effect of Emulsifiers. The results in Fig. 1 show compressibility readings made on bread when 2, 24, 48, 72, and 96 hours old. Six slices were taken from a separate loaf from each batch for the firmness determinations at each time interval. Triplicate sets of tests were made with each flour type so that each point on the curves is based on 18 readings.

It is quite evident that differences in softness of the 2 hour bread are insignificant and that there is an appreciable decrease in the rate of firmness development due to the addition of the emulsifiers. The average firmness readings for both flour types on 96 hour bread were 29.4 for the control loaves, 22.6 when using vegetable oil monoglyceride and 16.5 for the bread containing polyoxyethylene stearate. The two flour types are not identified in the figure since the tests with

flour No. 1 were made several weeks before those with No. 2 and with an increase in average room temperatures during this interval. This difference in temperature during storage of the bread could account for the difference in the rate of firmness development with the two flour types as will be discussed later.

There has been some dispute about the amount of deformation which should be employed in making firmness tests with the Baker Compressimeter and also as to whether the data conform to Hooke's

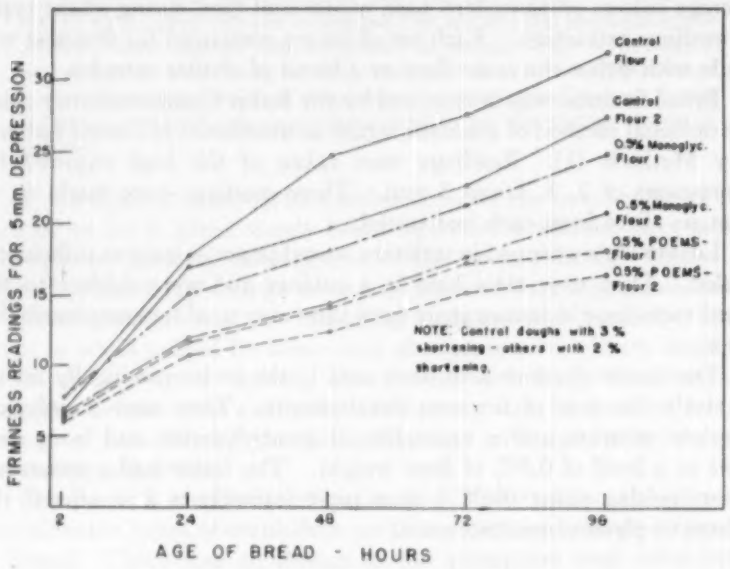

FIG. 1. Effect of age of bread on compressibility readings.

law. Fig. 2(b) shows the average firmness-deformation relationship of the control bread at various ages from the six series of tests which have just been discussed. Fig. 2(a) gives similar data for the bread containing polyoxyethylene stearate. The stress-strain relationships produced approximately straight lines in all cases when plotting deformations of 2, 3, 4, and 5 mm., but these lines extrapolated would not pass through the origin. This would seem to indicate that Hooke's law does not apply to such determinations. The regularity of results at different deformation levels show that the effect of the emulsifiers upon the rate of bread firmness development can be shown by employing any deformation within this range but that differences are greater in the upper part of the range since the lines are not parallel.

Effect of Temperature. One of the most impressive results from the use of an instrument such as the Baker Compressimeter was the revelation of a pronounced effect of storage temperature upon the rate of firmness development in bread. When judgment is used, instead of mechanical measurement, there is no way of noting whether bread firms more rapidly during the winter as compared with the summer season. It was soon discovered that shorter storage periods had to be employed during the cold weather season to stay on the scale of the instrument when reading the load needed for a 5 mm. depression of the slice.

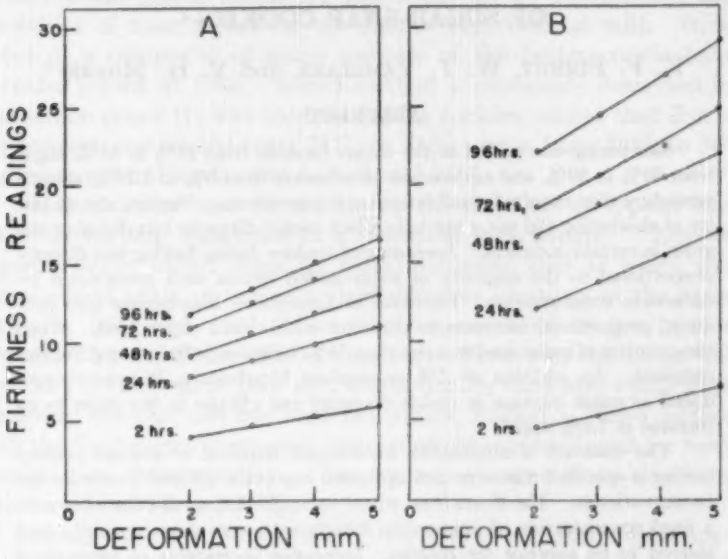

FIG. 2. (A) Relationship of firmness and deformation values obtained with bread of various ages containing polyoxyethylene stearate. (B) Values obtained with control bread of various ages.

A total of 13 pairs of loaves made without emulsifier and a similar number containing polyoxyethylene stearate, at a level of 0.5% of flour weight, were checked for compressibility after four days storage at uncontrolled room temperatures during the months of May through August. Average compressibility values for a 5 mm. depression were 24.3 for the control loaves and 15.4 when the bread contained the emulsifier. By way of comparison, averages were compiled for 18 series of tests made during the months of October through April on bread which had been held for only 3 days. Readings for a 5 mm. depression averaged 30.1 for the control bread and 20.6 when the polyoxyethylene stearate was included. These values average 27%

higher than those obtained in the summer with a 25% reduction in storage time.

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EFFECTS OF VARYING QUANTITIES OF SUGAR, SHORTENING, AND AMMONIUM BICARBONATE ON THE SPREADING AND TOP GRAIN OF SUGAR-SNAP COOKIES [1]

K. F. Finney, W. T. Yamazaki, and V. H. Morris [2]

ABSTRACT

Shortening was varied in the cookie formula from 25% to 35%, sugar from 50% to 80%, and ammonium bicarbonate from 0% to 3.25%, using a procedure that required small amounts of ingredients. Varying the quantity of shortening did not materially affect cookie diameter but did alter top grain in certain instances. Spreading of cookies during baking was directly proportional to the quantity of sugar added within each ammonium bicarbonate concentration. Increases in ammonium bicarbonate also produced proportional increases in diameter within each sugar level. When the quantity of sugar used was less than 55%, however, inferior top grain was obtained. An addition of .5% ammonium bicarbonate, in general, produced as much increase in cookie diameter and change in top grain as an increase of 7.6% sugar.

The quantity of ammonium bicarbonate required to produce cookies having a specified diameter and optimum top grain differed markedly between varieties. The flours from wheat varieties that spread the most with a fixed concentration of ammonium bicarbonate were those generally considered to be superior for cookies. Increasing increments of ammonium bicarbonate increased the pH of cookie dough from about 7.3 with no ammonium bicarbonate to about 7.9 for 2.25% regardless of variety. Further increases of bicarbonate to 3.25% were without additional effect on pH.

A formula including those quantities of sugar, shortening, and ammonium bicarbonate found to be most satisfactory for evaluating the cookie quality of different varieties of wheat is suggested.

The Tentative A.A.C.C. Cookie Method has been modified and adapted to a micro technique (1) for the quality characterization of soft wheat varieties. Before adopting this micro procedure for ex-

[1] Manuscript received September 30, 1949. Cooperative investigation between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, and Department of Agronomy, Ohio Agricultural Experiment Station.

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tended routine use in the Soft Wheat Laboratory, however, it seemed desirable to study the effect of varying quantities of the ingredients most effective in altering cookie characteristics. This paper presents data showing the relation of varying quantities of each of the ingredients sugar, shortening, and ammonium bicarbonate to spreading, thickness, and changes in top grain of sugar-snap cookies.

Materials and Methods

The flour referred to as "cookie standard" and used in studying the effect of varying quantities of sugar, shortening, and ammonium bicarbonate on cookie properties was made up by compositing small quantities of flour milled on the Buhler experimental mill. It consisted of a composite of many samples of the better cookie baking varieties grown in 1944. Micro method I previously described in a companion paper (1) was used for baking cookies, except that shortening content was varied from 25% to 35%, sugar from 50% to 80%, and ammonium bicarbonate from 0 to 3.75%.

Six flours were used in studies on the response of typical wheat flours to varying quantities of ammonium bicarbonate. They were experimentally milled from six wheat varieties, each of which was a composite of grain grown at widely different locations in the eastern states in 1943 and 1944. The varieties consisted of four soft red winters, Thorne, Trumbull, Wabash, and Kawvale, the latter being generally considered of poor soft wheat quality; one soft white winter, American Banner; and one hard red winter, Purkof. Micro method I with the fixed sugar/shortening ratio of 60/30 was employed for baking cookies from these varieties. The amount of ammonium bicarbonate was varied from 0 to 3.75%.

Baking was carried out at 400°F. for 9 to 10 minutes, depending on the amount of spreading. Diameter (D) was measured on all cookies. Thickness (T) and spread factor (D/T) were determined on all cookies excepting certain of them containing high sugar contents in combination with high ammonium bicarbonate levels. Along the rims of these latter cookies there was usually a ridge that interfered with making thickness measurements. These cookies also became brittle shortly after cooling, and were not considered to be palatable.

Results

Effect of Varying Quantities of Sugar, Shortening, and Ammonium Bicarbonate. Cookie baking data obtained in the studies with varying amounts of sugar, shortening, and ammonium bicarbonate, using the cookie standard flour, are summarized in Table I and presented graphically or photographically in Figs. 1 to 5.

TABLE I

DIAMETER, THICKNESS, AND SPREAD FACTOR OF COOKIES BAKED WITH VARYING SUGAR/SHORTENING RATIOS AT EACH OF SEVERAL AMMONIUM BICARBONATE LEVELS

NH_4HCO_3	Diameter (D)	Thickness (T)	D/T	Diameter (D)	Thickness (T)	D/T	Diameter (D)	Thickness (T)	D/T	Diameter (D)	Thickness (T)	D/T
	cm.	cm.		cm.	cm.		cm.	cm.		cm.	cm.	
	50/30[1]			55/30			60/25			60/30		
0.00	7.81	1.00	7.8	7.92	0.96	8.3	8.18	0.90	9.2	8.14	0.85	9.7
0.25	7.94	.98	8.1	8.01	.88	9.4	8.34	.87	9.7	8.35	.82	10.3
0.75	8.05	.91	8.9	8.43	.81	10.5	8.67	.78	11.1	8.59	.77	11.2
1.25	8.42	.83	10.2	8.85	.74	12.0	9.13	.72	12.8	8.94	.71	12.7
1.75	8.79	.79	11.2	9.30	.68	13.7	9.74	.65	15.2	9.34	.67	14.1
2.25	8.95	.80	11.3	9.56	.63	15.4	10.13	.58	17.7	9.87	.58	17.3
2.75	9.32	.74	12.7	9.96	.55	18.1	10.34	—	—	10.12	.54	18.9
3.25	9.76	.65	15.1	10.08	.53	19.1	10.49	—	—	10.46	.53	20.0
	60/35			65/25			65/30			65/35		
0.00	8.39	0.89	10.7	8.27	0.89	9.4	8.47	0.79	10.8	8.46	0.82	10.7
0.25	8.69	.72	12.2	8.44	.80	10.6	8.66	.76	11.4	8.66	.76	11.5
0.75	8.89	.70	12.8	8.92	.72	12.6	9.01	.66	13.7	8.83	.70	12.7
1.25	9.28	.62	15.0	9.35	.63	14.9	9.56	.57	17.1	9.24	.66	14.1
1.75	9.66	.57	17.1	9.83	.56	17.6	9.96	.54	18.6	9.69	.58	16.8
2.25	10.10	.52	19.7	10.10	—	—	10.28	—	—	10.04	.53	18.9
2.75	10.17	.52	19.5	10.41	—	—	10.64	—	—	10.29	—	—
3.25	10.71	.52	20.6	10.62	—	—	10.72	—	—	10.75	—	—
	70/25			70/30			70/35			75/30[2]		80/30[2]
0.00	8.53	0.77	11.1	8.72	0.74	11.9	8.71	0.73	12.1	8.88		9.03
0.25	8.80	.71	12.4	8.78	.75	11.7	8.92	.65	13.8	8.90		9.18
0.75	9.46	—	—	9.18	.65	14.2	9.10	—	—	9.34		9.62
1.25	9.95	—	—	9.52	—	—	9.50	—	—	9.85		10.29
1.75	10.22	—	—	9.92	—	—	9.89	—	—	10.21		10.60
2.25	10.60	—	—	10.39	—	—	10.20	—	—	10.67		—
2.75	—	—	—	10.65	—	—	—	—	—	10.86		—
3.25	—	—	—	10.81	—	—	—	—	—	10.95		—

[1] Ratio of sugar (%) to shortening (%).
[2] Diameters only were recorded because of ridges on the rim of each cookie.

The effects on cookie diameter of varying the shortening content at each of several ammonium bicarbonate levels are illustrated graphically in Fig. 1. Each point in Fig. 1 is the average of the data for all three sugar levels (Table I). Ammonium bicarbonate produced marked increases in cookie diameter whereas shortening had very little effect. Certain properties of the top grain (Fig. 2), however, are influenced by the ratio of shortening to sugar. For example, 25% shortening with 60% sugar resulted in well-defined top grains with a

rather undesirably hard and lean appearance. Increasing the shortening to 30% with 60% sugar resulted in cookies that had equally good top grains and were desirably softer and richer in appearance. When the shortening was increased to 35% with 60% sugar, dull and extremely soft appearing cookies with inferior top grains were obtained. Thus with 60% sugar in the formula, 30% shortening was preferable.

Increasing the sugar to 65% and 70% at the 25% shortening level resulted in top grains that were hard in appearance and more open than those with 60% sugar. These top grains for 65% and 70% sugar became closer and softer appearing, in general, as the shortening was increased.

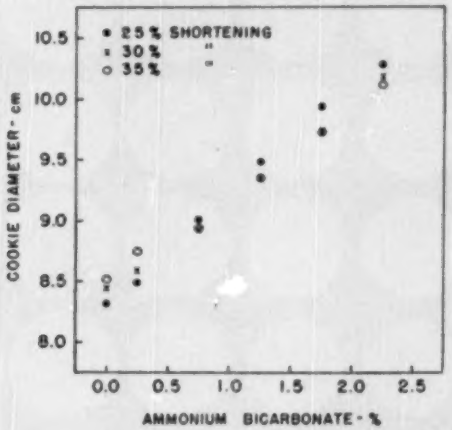

Fig. 1. Effect on cookie diameter of varying the shortening content from 25% to 35% at each of several ammonium bicarbonate levels.

When increased diameter and openness of top grain accompanying increases of ammonium bicarbonate are taken into account, equally good cookies were obtained with 30% shortening for all three sugar levels; whereas, the general appearance of the cookies containing 25% shortening was short of that desired. These observations together with the unsatisfactory top grains for 35% shortening with 60% sugar, and the necessity of increasing the quantity of sugar to overcome these undesirable top grains are factors that determined the choice of 30% shortening in all subsequent studies.

The effect on cookie diameter of varying quantities of ammonium bicarbonate and sugar in combination with a fixed shortening content of 30% is illustrated graphically in Fig. 3. Correlation coefficients and regression equations for the lines showing the relation between cookie diameter and quantity of ammonium bicarbonate within each

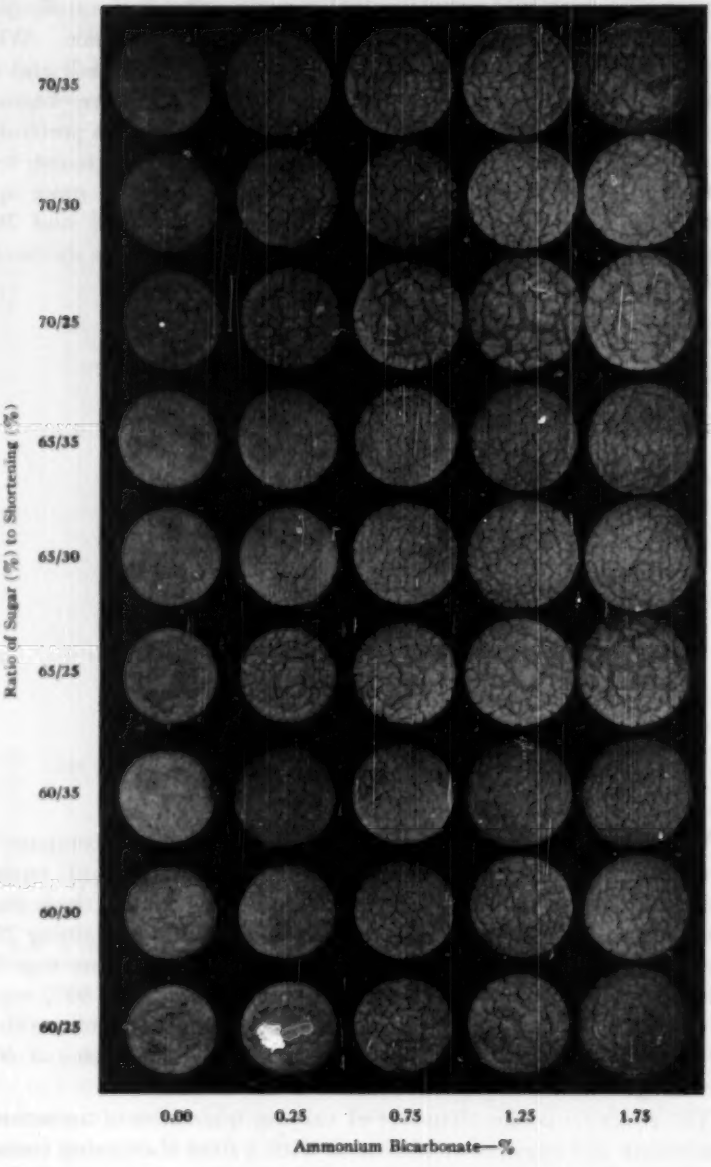

Fig. 2. Effect on cookie top grain of varying the ratio of sugar to shortening at each of several ammonium bicarbonate levels.

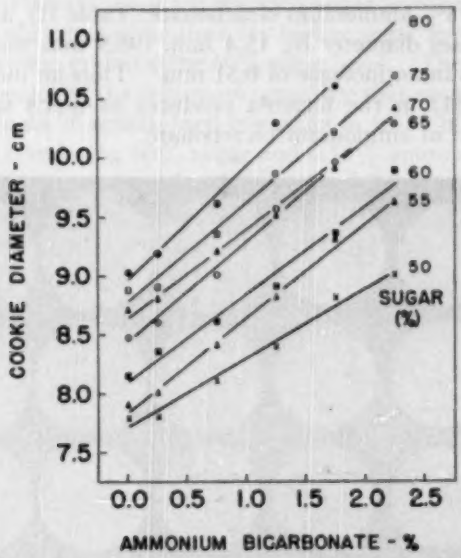

Fig. 3. Effect on cookie diameter of varying quantities of sugar and ammonium bicarbonate in combination with a fixed shortening content of 30%.

of seven sugar levels (50% to 80%) are given in Table II. Within each sugar level, the response to ammonium bicarbonate was linear over the range 0% to 2.25%. The average slope for all regression lines indicates that each .5% increment of ammonium bicarbonate increased cookie diameter by 3.9 mm.

As the concentration of sugar in the formula was increased from 50% to 80% within each ammonium bicarbonate level, cookie diameter increased. Referring to the cookie diameters calculated for a con-

TABLE II

CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS FOR COOKIE DIAMETER AND AMMONIUM BICARBONATE CONTENT FOR EACH OF SEVEN SUGAR LEVELS AT 30% SHORTENING

Sugar content	NH_4HCO_3 levels (n)	Corr. coeff. (r)	Regression equation Y =	Calculated diameter at 0.75% NH_4HCO_3 (Y)
%				cm.
50	6	0.992[1]	0.577X+7.715	8.15
55	6	0.997	0.791X+7.843	8.44
60	6	0.986	0.738X+8.098	8.65
65	6	0.994	0.852X+8.446	9.08
70	6	0.996	0.748X+8.638	9.20
75	6	0.992	0.838X+8.777	9.41
80	5	0.993	0.959X+8.973	9.69

[1] All correlation coefficients are significant beyond the 0.1% point.

centration of .75% ammonium bicarbonate (Table II), a 30% increase in sugar increases diameter by 15.4 mm. (96.9 mm minus 81.5 mm) and 1% results in an increase of 0.51 mm. Thus an increase of 7.6% sugar (3.9 ÷ .51) in the formula produces as much spreading as a 0.5% increment of ammonium bicarbonate.

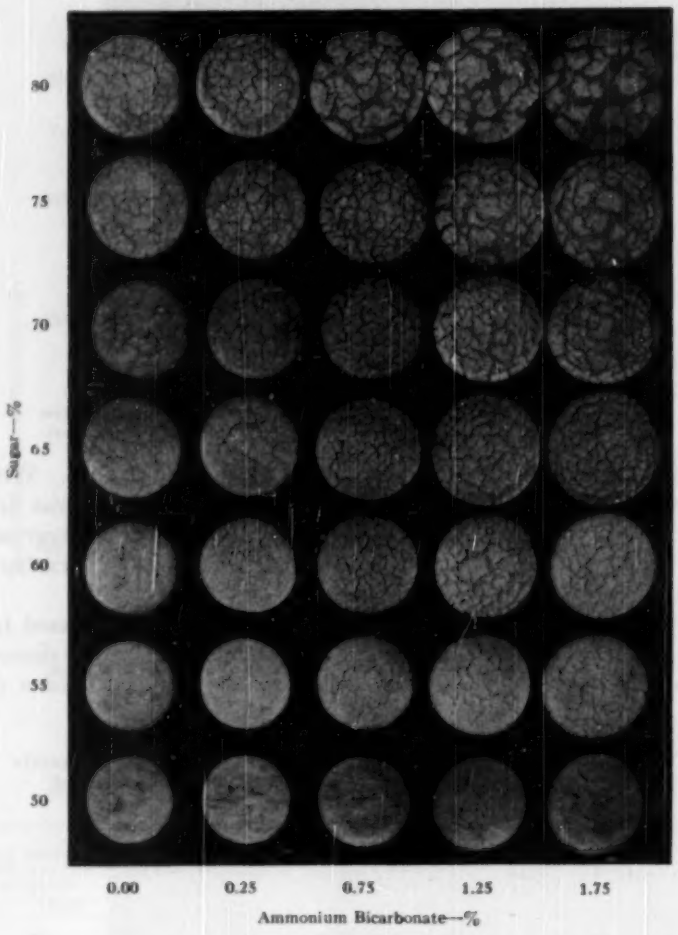

Fig. 4. Top grain and relative diameter of representative cookies containing varying quantities of sugar and ammonium bicarbonate.

The appearance of representative cookies containing varying quantities of sugar and ammonium bicarbonate is shown in Fig. 4. The effect of these two ingredients on top grain of cookies is of particular interest. The optimum top grains at or between the 1.25 and 1.75%

ammonium bicarbonate levels for the 55% sugar level are or would be (interpolating) slightly poorer than for higher sugar levels; and there is no satisfactory top grain for the 50% sugar level. These results suggest that 55% sugar is the minimum quantity that should be used in this cookie formula if satisfactory top grain is to be obtained. The cookie (Fig. 4) containing 60% sugar and 0.75% ammonium bicarbonate is one of the several examples of approximately optimum top grain. An optimum top grain for the 60% sugar level would be expected with about 1% ammonium bicarbonate. The cracks or valleys produced with 1.25% are considered to be too wide.

As was true for diameter, the width of the cracks increases as ammonium bicarbonate increases within each sugar level, and as sugar

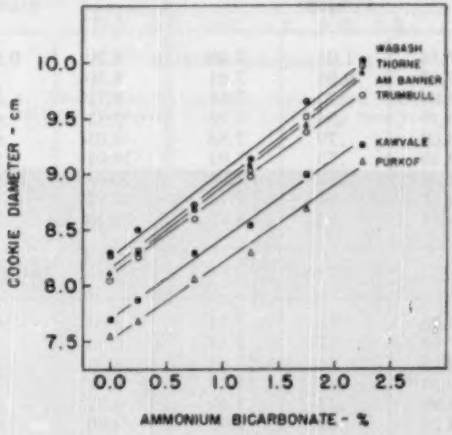

Fig. 5. Effect of varying quantities of ammonium bicarbonate on the cookie diameter of wheat varieties.

content increases within each ammonium bicarbonate level. Thus, for the flour used in this phase of the work, a cookie with a diameter of about 8.8 cm. and a satisfactory top grain was produced with the formula containing 70% sugar and .25% ammonium bicarbonate (Figs. 3 and 4). Interpolating in Fig. 3, a cookie with the same diameter and equally good top grain also can be produced with 10% less sugar providing the ammonium bicarbonate is increased to 1%. Similarly a cookie with a diameter of about 9 cm and a desirable top grain was produced with 80% sugar and no ammonium bicarbonate. A cookie of equal diameter and top grain also was produced with 15% less sugar when .75% ammonium bicarbonate was added.

Response of Wheat Varieties to Varying Quantities of Ammonium Bicarbonate. Wheat flours from six varieties were baked into cookies

at each of several ammonium bicarbonate levels for the purpose (1) of testing further the formula containing 60% sugar and 30% shortening, (2) of establishing the most satisfactory level of ammonium bicarbonate to use in the baking formula, and (3) of determining whether there are varietal differences in ammonium bicarbonate requirement.

TABLE III

DIAMETER AND THICKNESS OF COOKIES BAKED FROM SIX WHEAT VARIETIES AT EACH OF SEVERAL AMMONIUM BICARBONATE LEVELS TOGETHER WITH THE pH OF EACH COOKIE DOUGH

NH_4HCO_3	Diameter	Thickness	pH	Diameter	Thickness	pH
%	cm.	cm.		cm.	cm.	
	PURKOF			WABASH		
0.00	7.54	1.05	7.40	8.29	0.84	7.24
0.25	7.67	0.98	7.61	8.50	.78	7.50
0.75	8.06	.90	7.61	8.72	.74	7.60
1.25	8.29	.84	7.76	9.13	.68	7.80
1.75	8.68	.79	7.85	9.65	.61	7.77
2.25	9.10	.73	7.92	10.01	.56	7.86
2.75	9.21	.71	7.90	10.63	.48	7.84
3.25	9.61	.64	7.92	10.94	.45	7.91
3.75	9.71	.60	7.89	11.40	.45	7.86
	KAWVALE			TRUMBULL		
0.00	7.70	.94	7.41	8.05	.88	7.19
0.25	7.87	.92	7.55	8.25	.87	7.49
0.75	8.29	.86	7.67	8.59	.79	7.67
1.25	8.54	.81	7.77	8.97	.74	7.68
1.75	8.99	.73	7.89	9.37	.67	7.82
2.25	9.26	.69	7.90	9.70	.60	7.88
2.75	9.67	.63	7.87	—	—	—
3.25	10.01	.52	7.81	—	—	—
	THORNE			AM. BANNER		
0.00	8.27	.86	7.33	8.12	.87	7.27
0.25	8.32	.84	7.39	8.30	.83	7.55
0.75	8.69	.77	7.68	8.70	.79	7.65
1.25	9.03	.72	7.81	9.08	.71	7.82
1.75	9.51	.65	7.89	9.43	.64	7.80
2.25	9.97	.59	7.93	9.90	.60	7.88

These studies were concerned with the characterization and evaluation of flours recognized as having markedly different properties that make them of variable value for the production of soft wheat bakery products. The results are summarized in Table III and presented graphically or photographically in Figs. 5, 6, and 7. Correlation coefficients and regression equations for the lines showing the relation

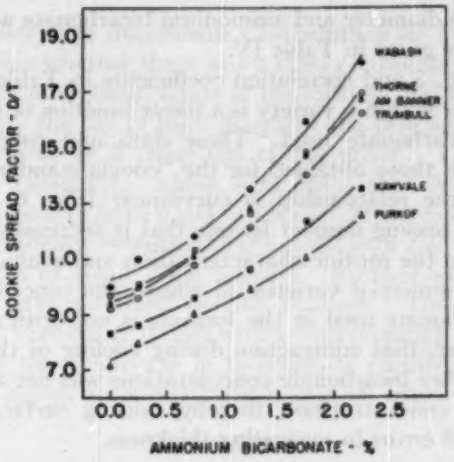

Fig. 6. Effect of varying quantities of ammonium bicarbonate on the cookie spread factor (D/T) of wheat varieties.

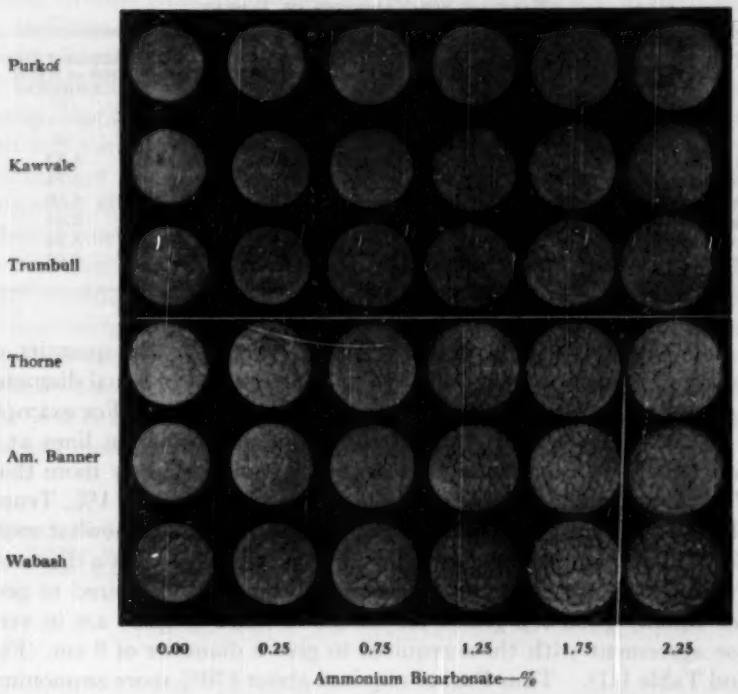

Fig. 7. Effect of varying quantities of ammonium bicarbonate on the top grain and relative diameter of cookies baked from Purkof, Kawvale, Trumbull, Thorne, American Banner, and Wabash wheats.

between cookie diameter and ammonium bicarbonate with each of the six varieties are given in Table IV.

Data in Fig. 5 and correlation coefficients in Table IV show that cookie diameter within a variety is a linear function of the quantity of ammonium bicarbonate used. These data and conclusions are in agreement with those obtained for the "cookie standard" flour. For *spread factor* the relationship is curvilinear (Fig. 6), the result of dividing an increasing number by one that is decreasing. These data indicate that in the routine characterization and evaluation of experimental and commercial varieties of wheat, the concentration of ammonium bicarbonate used in the formula is not critical. It was observed, however, that contraction during cooling of the cookies containing the higher bicarbonate concentrations was not as consistent as for the lower concentrations, thereby causing surface irregularities that introduced errors in measuring thickness.

TABLE IV

CORRELATION COEFFICIENTS AND REGRESSION EQUATIONS FOR COOKIE DIAMETER AND AMMONIUM BICARBONATE CONTENT FOR EACH OF SIX VARIETIES OF WHEAT

Variety	NH_4HCO_3 levels (n)	Corr. coeff. (r)	Regression equation Y =	Calculated diameter at 0.75% NH_4HCO_3 (Y)
				cm.
Wabash	6	0.990[1]	0.772X+8.246	8.82
Thorne	6	0.989	0.771X+8.163	8.74
Am. Banner	6	0.998	0.781X+8.103	8.69
Trumbull	6	0.999	0.720X+8.100	8.64
Kawvale	6	0.995	0.706X+7.714	8.24
Purkof	6	0.996	0.688X+7.517	8.03

[1] All correlation coefficients are significant beyond the 0.1% point.

The extent to which the six varieties differ as to the quantity of ammonium bicarbonate required to produce cookies of equal diameter or spread factor is strikingly illustrated in Figs. 5 and 6. For example in Fig. 5, a rule placed horizontally across the regression lines at a diameter of 9 cm. indicates that Wabash requires slightly more than 0.75%, Thorne and American Banner slightly more than 1%, Trumbull about 1.25%, Kawvale about 1.75%, and Purkof somewhat more than 2% ammonium bicarbonate to produce a cookie with a diameter of 9 cm. The quantities of ammonium bicarbonate required to produce equally good top grains for all six varieties (Fig. 7) are in very close agreement with those required to give a diameter of 9 cm. (Fig. 5 and Table III). Thus Purkof required about 170% more ammonium bicarbonate than did Wabash to produce a cookie of equal diameter and top grain.

Effect of Ammonium Bicarbonate Concentration on Dough pH. In order to determine whether there was a close relationship between the quantity of ammonium bicarbonate in the formula and the reaction of the cookie dough, the pH of each dough in the experiment discussed above was measured as it came out of the mixer. The results are summarized in Table III. These data show that doughs without ammonium bicarbonate have a pH of about 7.3; increasing quantities of bicarbonate gradually increase the pH, until with 2.25% ammonium bicarbonate, a pH of about 7.9 is reached. Further additions of the base, however, have no effect on the reaction. Thus the greater capacity of some varieties to spread with a fixed quantity of ammonium bicarbonate and the differences in bicarbonate requirement between varieties do not appear to be attributable to a pH effect.

Discussion

It appears that within reasonable limits, the proportions of sugar, shortening and ammonium bicarbonate are not critical in a cookie test baking formula from the standpoint of characterizing and differentiating varieties. The important consideration is to choose a formula which will produce normal, well-shaped cookies from flours representing a wide range of quality. Such a formula should produce cookies having large diameters, flat tops, and well developed cracks with flours from soft varieties, and cookies having much smaller diameters and a minimum of top grain from semihard to hard varieties. A formula containing 60% sugar, 30% shortening and 0.75% ammonium bicarbonate met these requirements with the flours tested.

Desirable diameters and top grains were obtained from flours generally considered to be of poor cookie quality (Purkof and Kawvale) by increasing the ammonium bicarbonate in the formula. Equal diameters and as good or better top grains were produced from flours generally considered of good cookie quality with *less sugar* and the same concentration of ammonium bicarbonate required by flours of poor and medium cookie quality.

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MICRO VERSUS MACRO COOKIE BAKING PROCEDURES FOR EVALUATING THE COOKIE QUALITY OF WHEAT VARIETIES [1]

K. F. FINNEY, V. H. MORRIS, and W. T. YAMAZAKI [2]

ABSTRACT

Cookie baking equipment and techniques suitable for evaluating the quality of 40 g. of flour are described. Cookie baking data for the "Tentative A.A.C.C." macro cookie test and three micro procedures indicate that all four methods are equally satisfactory for evaluating the cookie baking potentialities of wheat flours. With respect to the saving of time and ingredients, however, the micro procedures are markedly superior to the macro test from which they were derived. There is considerable latitude with respect to the type of mixing equipment that may be used for the preparation of cookie doughs, providing the mixing of the flour with the other creamed ingredients is held to a minimum.

The cookie baking formula and procedure originally proposed by Alexander (1) was modified by the 1941–42 Biscuit and Cracker Flours Committee (3) and recommended for the evaluation of soft wheat flours. This and other collaborative studies have resulted in a recommended formula and procedure called the "Tentative Cookie Method." The use of this test, however, in the quality research and variety characterization program of the Federal Soft Wheat Laboratory has been limited because of the relatively large quantity of flour required. Accordingly, it has been modified [3] and adapted to micro techniques for evaluating the cookie quality of small lots of flour obtained from strains developed in the wheat breeding programs. This paper describes the equipment and techniques of these micro procedures, and compares them to the A.A.C.C. tentative procedure for evaluating typical varieties recognized for their divergent potentialities as cookie flours.

Materials and Methods

The flours used were experimentally milled on the Buhler mill from twelve named varieties of wheat, each of which was a composite of

[1] Manuscript received September 30, 1949. Cooperative investigation between the Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, U. S. Department of Agriculture, and Department of Agronomy, Ohio Agricultural Experiment Station.

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[3] See companion manuscript, "Effects of varying quantities of sugar, shortening, and ammonium bicarbonate on the spreading and top grain of sugar-snap cookies."

grain grown in the eastern uniform nurseries[4] at eight stations in 1945. Two other flour composites were included, namely (1) a composite of all the variety composites and (2) a blend of flour from several good quality soft wheat varieties referred to as "cookie standard." Protein, ash, and cookie dough absorption of each flour is given in Table I.

The formula and quantity of each ingredient used in the "Tentative A.A.C.C." macro test and the three micro procedures are given in Table II.

For the Tentative A.A.C.C. macro procedure, nonfat milk solids were added as a 20% suspension, 33.75 ml. of which contained 6.75 g. of solids. When nonfat milk solids were added as a suspension in any

TABLE I

PROTEIN, ASH, AND COOKIE DOUGH ABSORPTION OF 14 FLOURS THAT WERE BAKED INTO COOKIES[1]

Sample	Protein	Ash	Absorption
	%	%	%
Cookie standard	9.8	0.41	21.5
Clarkan	9.2	.42	22.5
Minturki	8.8	.42	22.3
Kawvale	8.2	.43	22.5
Kharkof	8.9	.43	22.8
American Banner	8.1	.42	23.0
Trumbull	8.7	.42	22.8
Purkof	8.9	.42	22.8
Fairfield	7.9	.42	21.8
Wabash	8.7	.42	22.5
Blackhawk	9.8	.42	21.8
H. Q. × Kawvale	9.4	.42	22.0
Thorne	9.0	.42	22.3
Composite	8.8	.42	22.3

[1] on 14% moisture basis.

of the micro procedures, 6 ml. containing 1.2 g. of solids were used. Whipping 120 g. of nonfat milk solids into 528 ml. of water gave 600 ml. of the 20% suspension. Foam was removed by the vacuum pump method.

A Hobart mixer (Model C-10 equipped with a cake paddle and a 3-quart bowl) was used for all creaming and mixing operations in the tentative A.A.C.C. macro procedure. The Hobart mixer also was used in the micro procedures for preparing in one operation all of the first stage of creamed material required for one day of baking. The remaining creaming and mixing involved in the micro methods was carried out in a National-Swanson-Working nonrecording micromixer modified to give a head speed of 178 rpm, and to use a flanged and deeper bowl with a capacity of 25 g. to 50 g. of flour (Fig. 1).

[4] The grain for these studies was obtained from tests conducted in cooperation with the several State agricultural experiment stations in the Eastern United States.

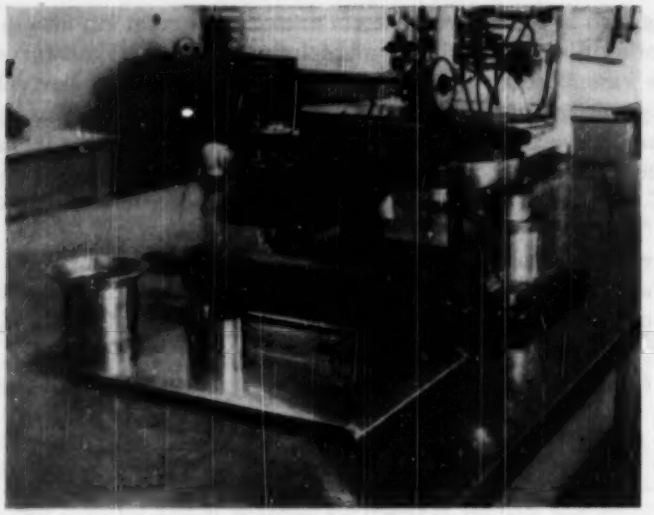

Fig. 1. Mixer, tray, rolling pin, and cutter used with the micro cookie procedures.

The cookie cutter was made from stainless steel tubing having an inside diameter of 2 13/32 inches and thickness of 3/64 inch (18 gauge), was 1½ inches in height, and was tapered from the outside inward on one end to give a sharp and rigid cutting edge. The trays were sheet aluminum 13 inches × 10 inches × .094 inch thick with riders .275 inch high and .5 inch wide running lengthwise along both sides and attached with brass screws which were countersunk on the bottom side of the tray. The pieces of equipment that were modified or con-

TABLE II

FORMULAE FOR THE A.A.C.C. MACRO AND THE THREE MICRO COOKIE BAKING PROCEDURES

Ingredient	Cookie method		Flour basis
	A.A.C.C. macro	Micro I II and III	
	grams	*grams*	%
Sugar	135.00	24.00	60.00
Shortening [1]	67.50	12.00	30.00
$NaHCO_3$	2.25	0.40	1.00
NH_4HCO_3	1.69	0.30	0.75
Nonfat milk solids	6.75	1.20	3.00
NaCl	2.25	0.40	1.00
Water	optimum	optimum	optimum
Flour [2]	225.00	40.00	100.00

[1] Hydrogenated vegetable shortening especially prepared for biscuit and cracker manufacturing.
[2] 14% moisture.

structed especially for the micro cookie procedures are shown photographically in Fig. 1.

Diameter (D) and thickness (T) were measured in millimeters and D/T was calculated for all cookies. Using a series of especially prepared cookies as reference standards, top grain was scored on the basis of 0 for a compact, hard-appearing cookie with no breaks, to 5 for a well-broken top containing numerous small "islands" characteristic of cookies baked from good quality cookie flours.

Macro Method. The tentative A.A.C.C. formula was modified slightly to conform with that used in the micro procedures, but in other respects the "macro" test as used in this study corresponds closely in important details to the Tentative A.A.C.C. test.

Sugar, shortening, and sodium bicarbonate were creamed for three minutes in a Hobart mixer on second speed, cutting down after each minute. Sodium chloride and ammonium bicarbonate were dissolved in the milk suspension and water in a 100 ml. beaker, after which the contents were added to the creamed mixture during mixing at low speed for one minute. Flour was incorporated by mixing for two minutes at low speed. After mixing, the dough was removed from the bowl with a spatula, care being taken to handle and compress the dough as little as possible. Doughs were spaced on trays, rolled once, and cut. That outside the stainless steel cutter was removed with a spatula before raising the cutter. Baking was carried out immediately for 10 minutes at 400°F. in a reel type oven.

Micro Method I. The first micro modification of the macro procedure involved the preparation of a sufficient quantity of sugar-shortening-sodium bicarbonate mixture for one day of baking by creaming 900 g. sugar, 450 g. shortening, and 15 g. sodium bicarbonate in the Hobart mixer for 4 minutes at high speed, scraping down at each half-minute interval. This creamed mass was sufficient for 37 weighings of 36.4 g. each on small squares of waxed paper.

Each cookie dough was prepared as follows: one 36.4 g. portion of the creamed mass of sugar, shortening, and sodium bicarbonate was transferred by means of a spatula to the micromixer bowl. The desired quantity of ammonium bicarbonate (.3 g.) was dissolved in 6 ml. of the milk suspension in a 10 ml. beaker, after which the contents were added to the bowl. The beaker was rinsed first with 2 ml. of sodium chloride solution containing 0.4 g. of salt and finally with 1.8 ml. to 3.3 ml. of water, depending on the requirement of the flour being tested. After creaming these liquids containing nonfat milk solids and sodium chloride for three minutes with the sugar-shortening-sodium bicarbonate creamed mixture, the flour was cut in with a spatula and then mixed for 10, 5, 5, and 5 seconds. The dough was dislodged with a

spatula from the bottom and sides of the bowl after each interval. After mixing, the dough was removed from the bowl and divided into two approximately equal parts with the aid of a spatula, care being taken to handle and compress the dough as little as possible. After spacing on a tray, the two doughs were rolled once with a wooden rolling pin and cut with a stainless steel cutter, dough outside the cutter being removed with a spatula before raising the cutter. Baking was carried out immediately for 10 minutes at 400°F. in a reel type oven.

Micro Method II. The second micro method differed from the first in that 15 g. of finely granulated sodium chloride and 45 g. of powered nonfat milk solids were creamed with the sugar, shortening,

TABLE III

PROPERTIES OF COOKIES BAKED FROM 14 WHEAT VARIETIES BY A MACRO AND THREE MICRO PROCEDURES

Sample	Diameter	Thickness	D/T	Top grain	Diameter	Thickness	D/T	Top grain
	cm.	cm.			cm.	cm.		
	MACRO METHOD				MICRO METHOD I			
Standard	8.92	0.74	12.13	4	8.84	0.77	11.49	5
Blackhawk	8.80	.79	11.19	3	8.70	.84	10.34	5
Wabash	8.72	.81	10.72	4	8.58	.84	10.24	5
Harvest Queen × Kawvale	8.70	.78	11.11	3	8.54	.84	10.16	4.5
Fairfield	8.65	.81	10.66	3.5	8.45	.84	10.23	4.5
Thorne	8.62	.84	10.30	4	8.52	.84	10.20	4.5
American Banner	8.61	.84	10.28	4	8.43	.87	9.66	4
Kawvale	8.52	.85	9.98	3	8.20	.91	9.06	4
Clarkan	8.50	.86	9.99	2	8.28	.88	9.43	3.5
Composite	8.48	.85	10.00	2.5	8.43	.90	9.39	4
Minturki	8.45	.87	9.71	2.5	8.21	.89	9.23	3.5
Trumbull	8.31	.89	9.34	3	8.10	.95	8.55	3
Kharkof	8.17	.94	8.75	1	7.85	1.00	7.83	2.5
Purkof	8.01	.96	8.38	1	7.76	1.03	7.57	2.5
	MICRO METHOD II				MICRO METHOD III			
Standard	8.90	0.80	11.07	5	8.79	0.76	11.72	4.5
Blackhawk	8.70	.83	10.23	5	8.72	.82	11.14	5
Wabash	8.69	.85	10.27	4.5	8.63	.83	10.74	5
Harvest Queen × Kawvale	8.50	.86	9.92	4.5	8.50	.84	10.32	4.5
Fairfield	8.45	.87	9.72	4.5	8.48	.86	9.92	4.5
Thorne	8.49	.88	9.70	4.5	8.39	.86	9.82	5
American Banner	8.36	.89	9.45	4.5	8.40	.87	9.75	4
Kawvale	8.22	.91	9.05	4.5	8.34	.87	9.73	3.5
Clarkan	8.28	.91	9.08	4	8.35	.89	9.53	4
Composite	8.37	.91	9.27	4.5	8.22	.87	9.42	3
Minturki	8.34	.90	9.23	4	8.29	.89	9.55	3.5
Trumbull	8.22	.95	8.63	3.5	8.17	.93	8.93	4
Kharkof	7.95	1.00	7.99	3	7.90	.97	8.27	2.5
Purkof	7.76	1.03	7.56	2.5	7.72	1.02	7.74	2

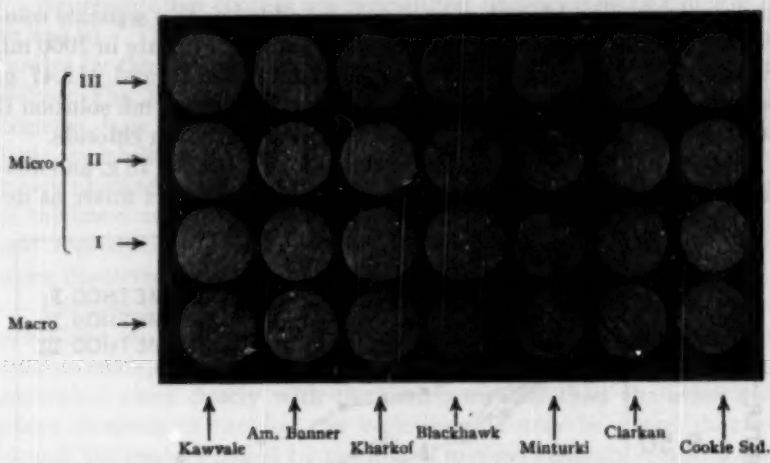

Fig. 2a. Top grains and relative diameters for cookies baked from six pure varieties and a composite cookie standard by a macro and 3 micro procedures.

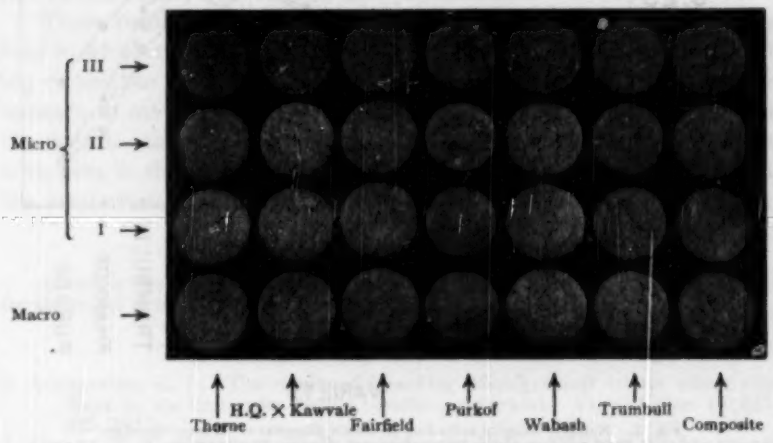

Fig. 2b. Top grains and relative diameters for cookies baked from six pure varieties and a composite by a macro and three micro procedures.

and sodium bicarbonate. A 38 g. weighing of this creamed mixture was creamed for three minutes with 9 to 10.5 ml. of water in which the .3 g. of ammonium bicarbonate was dissolved. The remaining procedures were carried out as described for Micro Method I.

Micro Method III. The third micro method differed from the second in the manner of adding the ammonium bicarbonate and sodium chloride. Since small quantities of ammonium bicarbonate affect cookie spreading (2), and ammonium bicarbonate in the form of dry salt or in solution decomposes appreciably at room temperature,

the ammonium and bicarbonate ions were added as two separate solutions. Solution A contained 127.68 g. sodium bicarbonate in 2000 ml. Solution B contained 135.53 g. ammonium chloride and 118.47 g. sodium chloride in 2000 ml. Five ml. solution A plus 3 ml. solution B furnished .3 g. ammonium bicarbonate and .4 g. sodium chloride.

Sugar 900 g., shortening 450 g., sodium bicarbonate 15 g. and nonfat milk solids 45 g. were creamed together in a Hobart mixer as described for Micro Method I. A 37.6 g. portion of this creamed mixture was creamed with 5 ml. solution A, 3 ml. solution B, and .8 to 2.3 ml. water in the micro mixer for three minutes at 178 rpm. Solutions A and B were dispensed from automatic pipettes and the water from a burette. The remaining procedures were as described for Micro Method I.

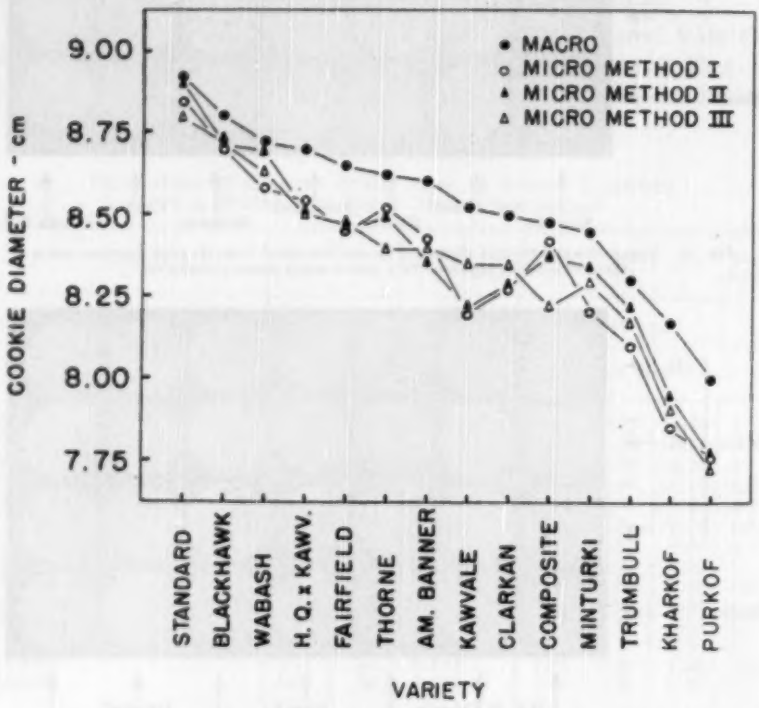

Fig. 3. Relative ranking according to cookie diameter of 12 pure varieties and two composites by a macro and three micro procedures.

Results

Cookie diameter (D), thickness (T), and spread factor (D/T) obtained for each of the 14 flours by the four cookie baking methods are summarized in Table III.

Representative cookies are reproduced photographically in Fig. 2 (a and b). The relative ranking of the 12 pure varieties and two composites by the four methods according to diameter are shown graphically in Fig. 3. Diameter instead of D/T was plotted against variety because data obtained in the laboratory indicated a comparatively large variability in thickness measurements for replicate cookie bakes which checked closely in diameter. Since D/T values are a function of thickness as well as diameter, it was believed that a more accurate and reproducible characterization of cookies could be obtained by using diameter alone.

The data show that the micro methods agree closely with the macro procedure in ranking the varieties. Micro Method III, now used in routine baking by the Federal Soft Wheat Laboratory, appears to agree somewhat more closely with the macro method than the other two micro methods in ranking the varieties. It may be noted that although the cookies baked by the macro method generaly spread somewhat more than those baked by micro procedures, the latter nevertheless showed a greater range in cookie diameters.

These results indicate that there is considerable flexibility in the way in which cookie doughs may be mixed without appreciably affecting either the rank of or spread between varieties. Furthermore, it appears to make little difference in variety evaluation work whether the flour is mixed in at low speed with a cake paddle or at high speed with pins in the planetaries and bowl, as for bread doughs, as long as the total amount of mixing action is kept at a minimum.

Acknowledgment

Credit is due Charles E. Bode, Federal Soft Wheat Laboratory, Wooster, Ohio, for assistance in certain phases of the cookie baking.

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THE NUTRITIONAL VALUE OF WHITE BREAD CONTAINING NONVIABLE DRIED YEAST[1]

R. D. SEELEY, H. F. ZIEGLER, JR., and R. J. SUMNER[2]

ABSTRACT

The nutritive value of white breads containing 1 to 3% dried, nonviable, debittered, brewers' yeast and nonfat milk solids was studied in feeding tests for growth on weanling rats. Baked bread was the only ingredient in the diets except for a fat-soluble vitamin supplement. Biological values were determined for some of the breads at the 10% protein level in rations supplemented with a salt and vitamin mixture. The feeding to weanling rats of white breads containing 1 and 3% dried yeast produced, respectively, increases in the daily weight gain of 0.34 g. and 0.66 g. above the gain produced with basic formula white bread. The weight gain of the rats receiving the white bread without dried yeast was 0.55 g. per day. The food utilization of the breads baked with 1 and 3% dried yeast was increased from 9.2 g. gain per 100 g. food intake for white bread without yeast to 12.3 and 14.7 g. gain, respectively. Similar increases were observed when white breads containing 1 and 3% nonfat milk solids plus dried yeast were fed to growing rats. Under the experimental conditions employed, dried yeast was a better supplement than nonfat milk solids since breads containing either 1% dried yeast or 3% nonfat milk solids were approximately equal in promoting growth of weanling rats when fed as the only source of food. However, the largest weight gains were observed when the bread contained both nonfat milk solids and dried yeast.

The inclusion of dried yeast in white bread did not produce any marked increase in the biological value of the bread proteins as measured by a nitrogen balance method. The small increases in the protein content of the breads containing dried yeast, and perhaps known or unknown members of the B complex in the yeast, appear to play a role in producing the increased growth response in rats.

The relatively low nutritive value of patent white flour or bread made with patent white flour as compared to whole wheat flour has been demonstrated by many investigators (5, 10, 15, 16) and has been attributed primarily to a loss in vitamins and to a lower biological value of the protein in the flour. Riggs *et al.* (17) observed that the "enrichment" of white flour in bread causes only a slight improvement in the growth response of rats. Westerman and Hall (23) found that the addition of calcium pantothenate and pyridoxine increases the growth of rats on an "enriched" white flour diet. Mitchell and Block (14) state that the limiting essential amino acid of white flour is

[1] Manuscript received August 12, 1949.
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lysine. Valine has also been reported as a limiting essential amino acid (12). Light and Frey (12) report that the supplementary value of nonfat milk solids and nonviable dried yeast to white bread is primarily due to this lysine content. Sure (19, 20, 21), in an extensive series of studies on the supplementation of cereal grains, observed that rats fed "enriched" white flour supplemented with 1 to 5% nonviable dried yeast exhibited large increases in weight gain and food utilization as compared to those fed unsupplemented "enriched" white flour. These increases were not entirely accounted for by the lysine content of the yeast. The diets employed by Sure contained adequate amounts of eight crystalline B-vitamins. However, the supplementary value of dried yeast for white flour was not determined in the presence of nonfat milk solids or in baked bread.

The following study was undertaken to determine the nutritive value of white breads containing 1 and 3% nonviable, dried, debittered brewers' yeast, as measured by rat growth when the breads were the sole ingredient in the diet except for a fat-soluble vitamin supplement. As most bread in this country is baked with nonfat milk solids, the growth response of rats fed bread containing dried yeast was studied in the presence and absence of this ingredient. Biological values measured by the nitrogen balance method in growing rats were conducted to determine the effect of these ingredients on the utilization of the protein of white bread.

Materials and Methods

The bread used in these experiments was made by the sponge dough process, using 72% extraction flour according to the basic bread formula given in Table I. The dried yeast and nonfat milk solids [3]

TABLE I

BASIC BREAD FORMULA

Ingredient	Parts
Flour	100.0
Water	62.0
Sugar	6.0
Salt	2.0
Hydrogenated Shortening	3.0
Baker's Compressed Yeast	2.0
Mineral Yeast Food	0.5
Diastatic Dri-Malt	0.5

were added at the dough stage, the percentages shown being based on the flour content. The dried yeast employed in these studies was a nonviable, debittered, brewers' yeast.[4] The bread was sliced, air-

[3] Spray-dried, nonfat milk solids from the Pevely Dairy Co., St. Louis, Missouri.

[4] Strain K, Anheuser-Busch, Inc., St. Louis, Missouri.

dried, and ground before being fed to the animals. Groups of eight weanling rats (4 males and 4 females) weighing between 45 and 55 g. were fed the various breads as the only ingredient in the diets, *ad libitum*, except for a fat-soluble vitamin supplement, for a 10-week growth period. Each rat received 800 units of vitamin A, 160 units of vitamin D, and 6 mg. of alpha-tocopherol per week. Weight gains and food consumption were recorded weekly.

Biological values were determined at the 10% protein level on some of the breads fed to growing rats, using the nitrogen balance technique of Mitchell (13). The diets and vitamin supplements used are recorded in Table II. Nitrogen content of the urine and feces was determined by a micro-Kjeldahl method.

The breads were analyzed for thiamin by the method of Hennessy and Cerecedo (8), for riboflavin by the method of Tobin and Rehm (22),

TABLE II

BREAD DIETS FOR BIOLOGICAL VALUE DETERMINATIONS *

White Bread (Dried)	81.2
Sucrose	3.8
Salt Mixture **	4.0
Cellu Flour	2.0
Crisco	9.0
	100.0

* The following crystalline vitamins were added per 1,000 g. of diet: 5 mg. thiamin hydrochloride, 10 mg. riboflavin, 5 mg. pyridoxine hydrochloride, 50 mg. calcium pantothenate, 20 mg. niacin, 1,000 mg. choline chloride, 400 mg. inositol, and 50 mg. p-amino benzoic acid.
** Wesson's modified Osborne-Mendel salt mixture.

for niacin by the microbiological technique of Landy and Dicken (11), for pantothenic acid by the method of Strong, Feeney and Earle (18), and for pyridoxine by the procedure of Atkin, Schultz, Williams, and Frey (1). Total nitrogen, ash, moisture, calcium and phosphorus were also determined on the air-dried bread.

Results

The growth response of weanling rats fed "enriched" white bread and breads baked with and without 1 and 3% nonviable, debittered, brewers' yeast and/or 1 and 3% nonfat milk solids is shown in Fig. 1. Over a ten-week period the rats on basic-formula white bread (curve with open squares) gained only 40 grams. Small increases in growth response were produced by "enriched" [5] white bread and the addition of 1% milk solids. One per cent dried yeast in white bread produced a weight gain of 68 g. over ten weeks, which was slightly greater than the weight gain of rats fed bread containing 3% of nonfat milk solids.

[5] Enriched with thiamin, riboflavin, niacin, and iron in accordance with flour standards (6).

Bread containing 3% dried yeast caused a weight gain of 92 g. over a ten-week period. The addition of dried yeast to white breads containing 1 and 3% of nonfat milk solids produced significantly greater weight gains in rats than bread containing only nonfat milk solids. The greatest growth (110 g.) was produced by bread containing 3% nonfat milk solids and 3% nonviable, debittered brewers' yeast (curve with open circles).

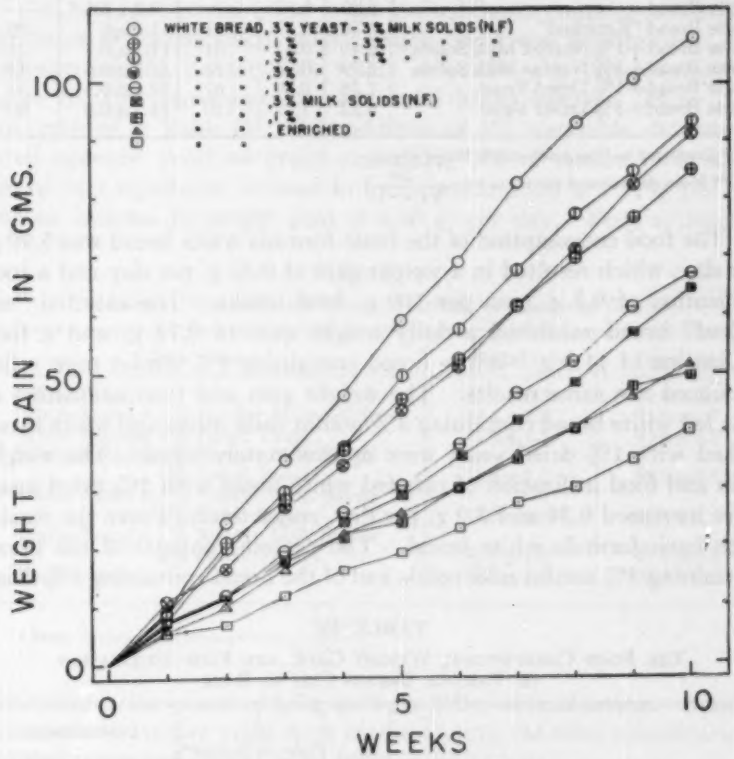

FIG. 1. The growth response of weanling rats fed, *ad libitum*, various breads.

The feeding of white breads containing nonfat milk solids and dried yeast results not only in increased weight gains as compared to those obtained with basic-formula white bread, but also in increased food consumption and food utilization. The food intakes, weight gains and food utilizations are recorded in Tables III and IV. These data were calculated for the usual six-week period. The food utilization of the various breads was not significantly different after a ten-week period.

TABLE III

THE FOOD CONSUMPTION, WEIGHT GAIN AND FOOD UTILIZATION OF VARIOUS BREADS FED TO RATS

Type of bread	Food intake g./day	Gain in body weight g./day	Increase* in body weight %	Food utilization	
				G. gain per 100 g. bread intake	Increase* %
White Bread	5.99	0.55	—	9.2±0.6**	—
White Bread "Enriched"	6.56	0.72	31	11.0±0.7	20
White Bread+1% Nonfat Milk Solids	6.40	0.72	31	11.2±0.7	22
White Bread+3% Nonfat Milk Solids	6.79	0.84	53	12.4±0.6	35
White Bread+1% Dried Yeast	7.28	0.89	62	12.2±0.5	33
White Bread+3% Dried Yeast	8.22	1.21	120	14.7±0.8	60

* Compared to Unsupplemented White Bread.

** Mean deviation of the mean $=\epsilon=\sqrt{\frac{\Sigma d^2}{n(n-1)}}$

The food consumption of the basic-formula white bread was 5.99 g. per day, which resulted in a weight gain of 0.55 g. per day and a food utilization of 9.2 g. gain per 100 g. food intake. The rats fed "enriched" bread exhibited a daily weight gain of 0.72 g. and a food utilization of 11.0 g. White bread containing 1% nonfat milk solids produced the same results. The weight gain and food utilization of rats fed white bread containing 3% nonfat milk solids and white bread baked with 1% dried yeast were approximately equal. The weight gain and food utilization of rats fed white bread with 1% dried yeast were increased 0.34 and 3.0 g. per day, respectively, above the results with basic-formula white bread. The protein contents of the bread containing 3% nonfat milk solids and of the bread containing 1% dried

TABLE IV

THE FOOD CONSUMPTION, WEIGHT GAIN, AND FOOD UTILIZATION OF VARIOUS BREADS FED TO RATS

Type of bread	Food intake g./day	Gain in body weight g./day	Increase* in body weight %	Food utilization	
				G. gain per 100 g. bread intake	Increase* %
White Bread+3% Nonfat Milk Solids	6.79	0.84	—	12.4±0.6**	—
White Bread+3% Nonfat Milk Solids 1% Dried Yeast	8.14	1.24	48	15.2±0.2	23
White Bread+3% Nonfat Milk Solids 3% Dried Yeast	8.70	1.64	95	18.9±0.4	52
White Bread+1% Nonfat Milk Solids 3% Dried Yeast	8.10	1.36	62	16.8±0.5	35

* Compared to 3% Nonfat Milk Solids Bread.

** Mean deviation of the mean $=\epsilon=\sqrt{\frac{\Sigma d^2}{n(n-1)}}$.

yeast (Table VI) were almost identical (12.7 and 12.8%, respectively). The bread containing 3% dried yeast produced a still larger weight gain (1.21 g./day) and food utilization (14.7 g. gain per 100 g. of food intake). These data demonstrate that when white bread is fed, *ad libitum*, as the sole food source to the weanling rat on an equal percentage basis, the addition of dried yeast is more efficient for growth than nonfat milk solids.

As most commercial bread in the United States contains milk solids, the value of adding dried yeast to such bread was determined. The inclusion of 3% nonfat milk solids in bread is a "representative" figure for this ingredient in commercial bread baking. These data are recorded in Table IV. The addition of 3% nonviable, debittered, dried brewers' yeast to bread containing 3% of nonfat milk solids produced a significant increase in food consumption of 1.91 g. per day and an increase in weight gain of 0.80 g. per day. Food utilization

TABLE V

BIOLOGICAL VALUES AND DIGESTIBILITIES OF VARIOUS BREADS

Type of bread	Biological value	Digestibility
White Bread	51.7±1.3*	92.0±0.2*
White Bread+3% Nonfat Milk Solids	54.1±1.5	91.9±0.7
White Bread+3% Dried Yeast	51.8±1.5	90.6±0.5
White Bread+3% Nonfat Milk Solids 1% Dried Yeast	51.6±1.5	89.5±0.5
White Bread+3% Nonfat Milk Solids 3% Dried Yeast	52.3±1.1	88.1±0.5
White Bread+1% Nonfat Milk Solids 3% Dried Yeast	51.7±2.0	91.2±0.9
Lactalbumin	84.2±1.1	97.4±0.5

* Mean deviation of the mean $= \epsilon = \sqrt{\frac{\Sigma d^2}{n(n-1)}}$.

was raised to the extent of 6.5 g. gain per 100 g. of food intake. Similar increases in nutritive value were produced with the other combinations of dried yeast and nonfat milk solids in white bread.

The value of dried yeast as an additive to bread has been attributed largely to its lysine content. Biological values of some of the breads used in the growth studies were determined in growing rats, using the nitrogen balance method. The rations were compounded so as to contain 10% protein supplied by the bread. The results are given in Table V. Although the biological values and digestibility are discussed as protein utilization, the nitrogen balance method actually measures nitrogen utilization which is assumed to be related directly to the protein utilization.

The addition of 3% of nonfat milk solids and 3% of dried yeast

either alone or in combination did not produce any marked increase in the biological value of the proteins of the baked bread. The largest biological value of 54.1% for bread containing 3% of nonfat milk solids was not significantly greater ($P = 0.25$) [6] than that for the white bread. For the number of animals used in these determinations, an increase of 4 in biological value would have to be obtained to be statistically significant ($P = 0.05$). Larger numbers of animals would be required to determine smaller differences in biological values of these breads. The average biological value of 51.7% for white bread made with flour of 72% extraction compares well with the value of

TABLE VI

CHEMICAL COMPOSITION OF BREADS

Type of bread	Moisture %	Total protein %	Calcium %	Phosphorus %	Ash %	Thiamine γ/g.	Riboflavin γ/g.	Niacin γ/g.	Pantothenic acid γ/g.	Pyridoxine γ/g.
White Bread	7.91	12.0	0.10	0.12	2.55	0.9	1.1	12.1	5.2	0.6
White Bread "Enriched"	7.91	12.3	0.10	0.12	2.54	3.9	2.6	35.8	5.2	1.1
White Bread +1% Milk Solids*	7.78	12.6	0.14	0.13	2.61	1.1	1.1	12.7	5.5	1.0
White Bread +3% Milk Solids*	7.81	12.7	0.15	0.14	2.72	1.1	1.5	11.0	4.6	1.1
White Bread +1% Dried Yeast	7.90	12.8	0.10	0.14	2.61	2.2	1.1	19.9	6.3	1.2
White Bread +3% Dried Yeast	8.01	13.4	0.09	0.17	2.69	4.1	2.2	25.6	7.0	2.1
White Bread +3% Milk Solids* 1% Dried Yeast	8.43	13.3	0.17	0.16	2.68	2.0	1.3	19.8	5.5	0.9
White Bread +3% Milk Solids* 3% Dried Yeast	8.03	13.9	0.18	0.18	2.82	3.5	2.4	22.7	6.5	2.1
White Bread +1% Milk Solids* 3% Dried Yeast	7.93	13.8	0.12	0.17	2.54	3.9	1.7	26.4	6.4	1.6

* Nonfat Milk Solids.

51.2% reported by Henry and Kon (4) for white bread made with flour of 70% extraction.

The digestibility of the protein of the white bread was decreased slightly by the addition of 3% dried yeast. The lowest digestibility of the protein of the breads studied was 88.1% for white bread containing 3% each of dried yeast and nonfat milk solids. The digestibility of the protein of the white bread made by the basic formula was 92.0%.

The increase in food utilization observed in the growing rats with dried yeast does not seem to be largely the result of amino acid supple-

[6] Calculated by Fisher "t" values (7).

mentation. As these determinations were conducted on diets of equal protein content containing eight crystalline B-vitamins plus 2% of a salt mixture, the biological values represent protein utilization *per se*. It may be possible that when the breads are fed as the sole food source in the diet of the growing rat, the B-vitamins and other essential substances in the ration may not produce the same protein utilization as they do when measured under the conditions of the biological value determination.

The chemical analyses of the breads for moisture, protein, mineral elements, and B-vitamins, as air-dried for the nutritional studies, are recorded in Table VI. The addition of nonfat milk solids and dried yeast produced increases in the protein content of about 1 to 2% on the air-dry basis of approximately 8% moisture. The addition of nonfat milk solids increased the calcium content, as would be expected. Yeast did not affect the calcium content, but produced small increases in the amount of phosphorus.

Except for a slight increase of thiamin in the 3% dried yeast bread, the levels of thiamin, riboflavin, and niacin in the breads containing dried yeast or nonfat milk solids did not exceed "enriched" white bread. The addition of dried yeast to the white bread produced small increases in the levels of pyridoxine and pantothenic acid. The growth response of the rats on white bread containing dried yeast cannot be attributed entirely to the small increase in the content of these two vitamins, as Sure (20) has reported that the addition of dried yeast to "enriched" white flour markedly improved the nutritive value in the presence of a supplement of eight synthetic B-vitamins in the diet.

Discussion

The inclusion of nonviable, debittered, dried brewers' yeast in white bread increased the nutritive value markedly, even in the presence of 1 and 3% of nonfat milk solids, as measured by rat growth. The increased growth response may have resulted from (a) an increase in the biological value of the bread proteins, (b) an increase in the mineral content, (c) an increase in the vitamin content, (d) the higher protein content of the bread.

Sure (21) reported that the increase in protein efficiency of "enriched" white flour supplemented with 3 to 5% of dried yeast was greater than could be obtained with a quantity of lysine equal to the dried yeast in a diet containing a supplement of eight crystalline B vitamins. Sure did not add valine to his diets. In our determinations of the biological value of the various breads, the addition of either dried yeast or nonfat milk solids at the 3% level or lower did not

produce any significant increases in biological value. Henry *et al.* (9) in an excellent study on the biological value of white bread using the nitrogen balance method, observed that "the increase in biological value of the nitrogen of white bread caused by the addition of milk was slight." These authors further state that at these low levels of admixture (2 and 6% milk solids) there is no supplementary relationship between the milk and bread proteins. Although dried yeast contains 3.5% lysine (21) and is, therefore, an excellent source of this substance, the amounts of lysine and valine which it provides at the low level employed evidently were not enough to produce a large increase in the biological value of the bread proteins.

An important mineral deficiency of white bread is calcium (9). The improved growth response obtained with the addition of nonfat milk solids may be partially the result of the calcium which it provides as reported by Henry *et al.* (9). In the case of white bread containing dried yeast there is no increase in calcium content of the bread. The possibility of other minerals from dried yeast having an effect on growth will require further investigation with various mineral mixtures included in the rat diets.

The bread made with dried yeast did not contain larger amounts of thiamin, riboflavin or niacin than the "enriched" bread. Westerman and Hall (23) have observed that the addition of calcium pantothenate and pyridoxine improved the growth of rats on a B-complex-free, 20% casein diet plus "enriched" flour. However, Sure (20) observed that rat growth was improved by the inclusion of 1 to 3% dried yeast even in a ration containing an adequate supplement of 8 crystalline B vitamins. Cannon (4), using the rat repletion technique, observed that the addition of 3% dried yeast to a bread containing 2% of nonfat milk solids fed in a ration containing 6 crystalline B vitamins and a liver concentrate increased the nutritive value 20 to 33%, practically equalling whole wheat bread. Part of the increase in the growth response of rats fed white bread containing dried yeast under the conditions of the experiments employed is the result of an increased B vitamin content. However, as observed by Sure and by Cannon, the growth response may occur even in the presence of known B-complex supplements.

The increased protein content of the breads containing dried yeast and nonfat milk solids undoubtedly is a factor in improving growth response of rats fed the various baked breads. The fraction of ingested protein utilized by the rat for maintenance declines as the protein intake increases (2). Thus, rats receiving breads of higher protein content or rats with an increased food consumption will have a greater fraction of protein available for growth. Food utilization will be

increased in a similar manner. Mitchell observed that when paired-feeding experiments were conducted with rats, the difference between the nutritive values of "enriched" bread and bread containing 6% nonfat milk solids was less than with *ad libitum* feeding, although the superiority of the milk bread was still evident. The protein contents of the diets were not equalized in these experiments.

The increased growth response of rats fed white bread containing dried yeast is not primarily due to a large increase in the biological value, but appears to be the result of a higher vitamin and protein content which increases the food and protein consumption. Further experiments are in progress to determine the exact nature of the factors which produce the larger growth responses when white bread is supplemented with dried yeast. The white bread which contained both dried yeast and nonfat milk solids at the 3% level had the highest nutritive value, as measured by rat growth, in these studies.

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PREPARATION OF WHEAT FLOUR PENTOSANS FOR USE IN RECONSTITUTED DOUGHS[1]

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ABSTRACT

The separation of wheat-flour pentosans of satisfactorily low nitrogen content for baking tests was accomplished either by selective adsorption of the proteins of a heated, centrifuged flour extract on a suitable agent, or by precipitation of the proteins with the barium hydroxide-zinc sulfate reagent of Somogyi; dialysis then removed most of the remaining nitrogenous and carbohydrate impurities. The extracts were heated to destroy pentosanase activity. Yields were about 8 and 5 g. of pentosans per kg. of flour with the adsorption and the precipitation method respectively. The precipitation method gave a product of higher purity and of lower average molecular weight, although pentosans obtained with either method showed the chemical characteristics noted by earlier workers, particularly gel formation upon oxidation.

Under the conditions of this study, soluble pentosans had little effect on the baking performance of doughs reconstituted without the water-soluble fraction of flour, but the handling properties of the doughs themselves were distinctly modified. The pentosans corrected to a large degree the slack softness, wet surface, and lack of normal stickiness shown by doughs reconstituted with only gluten and starch. Improvements in volume, grain and texture were small.

The importance of water-soluble components in the bread-baking performance of flours from some wheat varieties was demonstrated by Finney (6), who separated the glutens, starches, and water-soluble fractions of flours and recombined them in the original proportion and

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in different proportions before baking them into bread. Among constituents known to be present in the water-soluble fraction of flour, the pentosans have been studied in some detail by Baker, Parker, and Mize (2); the observed formation of an irreversible gel upon treatment of pentosan solutions with certain oxidizing agents used as bread improvers suggested to these workers that soluble pentosans may have an important influence on dough properties. It seemed desirable, therefore, to determine more clearly the actual contribution of pentosans to the baking behavior of a flour. To facilitate such studies, improved methods were developed for the preparation of pentosans in sufficient quantity for reconstitution baking.

Methods and Materials

Pentosans were determined routinely by the colorimetric method of Brown (3), which gave results in satisfactory agreement with those obtained by a furfural distillation method (1). The baking formula of Finney and Barmore (7), with optimal bromate, was used in conjunction with the A.A.C.C. Standard Baking Procedure (1), and mixing times were determined with the National Recording Mixograph.[3] Doughs were reconstituted with wet gluten by the method of Sandstedt, Jolitz, and Blish (10), and the water-soluble fractions were prepared according to the recommendations of Finney (6). A single uniform lot of starch was used for all doughs. Glutens were stored in the frozen state, and water-soluble preparations were dried by lyophilization. The flours used were straight-grade, unbleached flours experimentally milled from samples of pure varieties. One sample contained 13.1% protein (at 14% moisture) and was milled from Turkey wheat grown in Texas; the other was an 8.6% protein flour from Purkof, a semi-hard red winter wheat, grown in Indiana.

Preparation of Pentosans. Various types of adsorbing agents were investigated for their selectivity toward the nitrogen-containing materials of flour extracts in an effort to separate the pentosans and proteins by a method which would give good yields of pentosans and allow recovery of proteins by elution. The agents used included Norite A, kaolin, bentonite, permutit, synthetic resins of the Amberlite type, and the activated clays marketed by the Filtrol Corporation.[3] Of these, Special Filtrol was found to be the most satisfactory from the standpoint of efficiency of protein adsorption, ease of handling, and inertness toward pentosans. Up to 90% of the non-dialyzable nitrogen of a flour extract could be removed by this agent, while the pentosan content was scarcely affected. However, no effective method of recovery of the adsorbed protein has been devised.

[3] Mention of trade names of material and equipment does not constitute endorsement by the Department of Agriculture.

It was necessary to heat flour extracts to 90° to 95°C. for 3 to 4 minutes to prevent a rapid decrease in viscosity of the extracts. Although the heating caused precipitation of 30 to 50% of the total nitrogen of the extracts, the viscosity remained virtually unchanged. These observations suggested that pentosans were the main contributor to the viscosity of the extracts and that enzymatic action upon the pentosans was responsible for the viscosity changes observed. Baker, Parker, and Mize (2) had observed evidence of pentosanase activity in bran extracts, and Dr. Parker [4] informed us that subsequent work had shown the presence of a pentosanase in flour. Accordingly, the identity of the enzyme in the flour extracts was established by the viscosity-decreasing effects of the extracts upon solutions of purified pentosans. The adsorption agents failed to remove the pentosanase completely from solution.

Another method of preparation of pentosans was developed from an investigation of the effect of protein-precipitating agents on the solubility of pentosans. Treatment of a flour extract with the barium hydroxide-zinc sulfate reagent of Somogyi (11) produced sparkling clear filtrates containing practically none of the original non-dialyzable nitrogen and about 60% of the original pentosans of the extract. This reagent also lowered the pentosanase activity of unheated extracts to almost insignificant levels.

A more detailed description of the two methods for the isolation of soluble flour pentosans follows. Extracts were prepared by stirring a quantity of flour with four parts of the 0.1%, pH 6.8, phosphate buffer of Dill and Alsberg (5) for 30 minutes. After removal of the solids by centrifugation, the extract was heated to 90° to 95°C. for 3 to 4 minutes and cooled immediately. The precipitated material was removed by centrifugation. In the adsorption method, the supernatant was shaken or stirred for 30 minutes with five grams of Special Filtrol per 100 ml. of solution. For best results the pH for this step should be in the range of 5.5 to 6.0. Actually, the pH usually was found in this range after the addition of Filtrol to the extract. The Filtrol was then removed by centrifugation, and the supernatant dialyzed in Visking [3] cellulose tubing against distilled water, concentrated under vacuum below 40°C., and lyophilized.

In the second method, one volume each of 0.3 *N* barium hydroxide and 5% zinc sulfate were added successively, with stirring, to 3 volumes of the supernatant after heat treatment. The resulting solution should be neutral or only very slightly alkaline. The heavy, white precipitate was removed by filtration, and the filtrate was dialyzed, concentrated, and lyophilized as described above.

[4] Personal communication.

Characterization of Pentosans. Typical preparations of pentosans obtained by the adsorption method contained 70 to 80% pentosans and 3 to 5% protein without further purification. About 8 g. of pentosans were obtained per kg. of flour. Barium-zinc preparations contained up to 90% pentosans and 2 to 3% protein; about 5 g. were obtained per kg. of flour.

Preliminary ultracentrifuge examination of material prepared by the adsorption method showed two peaks of about equal area. The sedimentation constant of the sharper, more slowly moving boundary corresponded to a minimum molecular weight of about 15,000, disregarding corrections for asymmetry or hydration. A preparation by the barium-zinc method was single-boundaried without marked spreading, and therefore appeared to be a relatively homogeneous preparation. The observed sedimentation constant also corresponded to a minimum molecular weight of about 15,000. Osmotic pressure measurements by the method of Bull (4) on the same preparations

TABLE I

COMPARISON OF THE EFFECTS OF PENTOSANS AND COMPLETE WATER-SOLUBLE FRACTIONS ON LOAF VOLUMES OF RECONSTITUTED DOUGHS[1]

	Turkey		Purkof	
	Average loaf volume	Standard deviation	Average loaf volume	Standard deviation
	cc.	*cc.*	*cc.*	*cc.*
Control (gluten plus starch)	695	13	600	19
Control plus pentosans	715	14	665	14
Control plus complete water-soluble fraction	835	18	800	7

[1] Gluten content of all doughs equivalent to that of 100 g. of flour at 12% protein. Pentosans and water-soluble fraction added in ratio to gluten as found in original flour.

gave average molecular weight values of approximately 22,000 for the barium-zinc preparation and approximately 39,000 for the Filtrol preparation. Apparently the barium-zinc reagent precipitated the larger pentosan particles as well as the proteins of a flour extract.

The pentosans obtained by these methods were slowly soluble in water to form clear, viscous solutions. A purplish red color was obtained with iodine. Oxidizing agents produced gels which did not liquefy on standing and which were little affected by vigorous stirring.

Baking Studies. Baking results obtained with reconstituted doughs prepared from the two flours are presented in Table I.

These values show that the complete water-soluble fractions produced volume responses of 140 and 200 cc. for the Turkey and Purkof doughs, respectively, while the volume increases for the

pentosans were only 20 and 65 cc. The slight effect of the pentosans can be partially accounted for by the small amounts of water-soluble protein remaining in the pentosan preparations. Neither the source nor method of preparation of the pentosans had an effect on the results obtained. Doughs without added pentosans were soft and slack, were not sticky, and had a wet, shiny surface. The doughs to which pentosans only had been added were firm and dry, and sticky to a normal degree. The grain and texture of loaves baked with the Purkof gluten were slightly improved by pentosans, but loaves with Turkey gluten were unaffected. A small decrease in absorption was noted for doughs from both flours in the absence of pentosans.

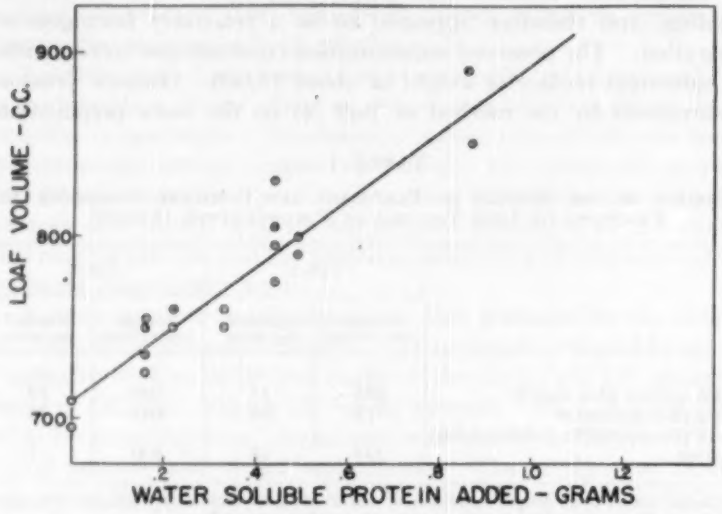

Fig. 1. Scatter diagram showing relation between loaf volume and amounts of protein in water-solubles added to reconstituted doughs. The original flour contained 0.87 g. water-soluble protein per 100 g. The gluten content of all doughs was equivalent to that of 100 g. of flour at 12% protein.

The small contribution of pentosans to loaf volume responses was also shown by use of a water-soluble fraction from which most of the proteins, but little of the pentosans and dialyzable constituents, had been removed by treatment with Special Filtrol. By the addition in varying amounts of treated or untreated fractions, reconstituted doughs were obtained which contained varied amounts and ratios of pentosans and water-soluble proteins. By this means a comparison of their relative effects on loaf volume was possible. The results obtained with Turkey flour fractions are presented in Figs. 1 and 2. Fig. 1 shows loaf volumes plotted against the amounts of protein contained in the added water-soluble material. The small dispersion

of points around the regression line emphasizes the highly significant correlation coefficient of + 0.98 which was obtained. A much lower order of correlation is obvious in Fig. 2, where the same loaf volume data are plotted against the amounts of pentosans contained in the added materials. The dispersion of points around the regression line is much greater, and the correlation coefficient is + 0.77. The nitrogenous constituents, therefore, appear to be responsible for the loaf-volume-increasing effects of the water-soluble fraction. However, the baking experiments described do not exclude the possibility that water-soluble proteins may require the presence of pentosans to produce their optimum effect.

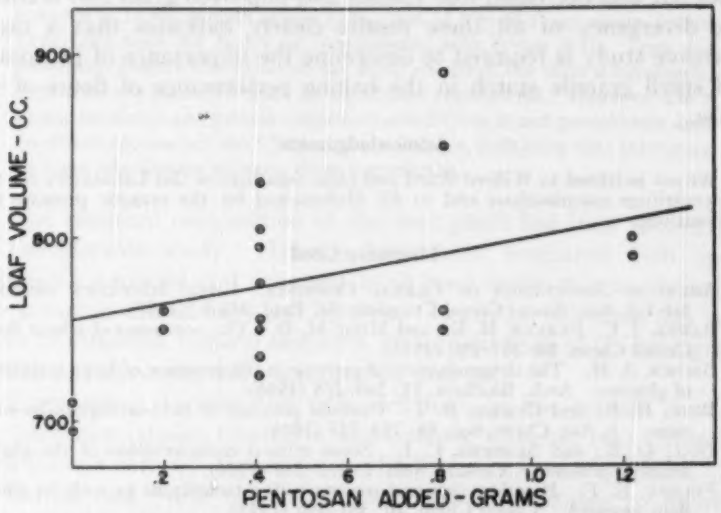

Fig. 2. Scatter diagram showing relation between loaf volume and amounts of pentosans in water-solubles added to reconstituted doughs. The original flour contained 0.81 g. soluble pentosans per 100 g. The gluten content of all doughs was equivalent to that of 100 g. of flour at 12% protein.

Discussion

The marked effect of temperature on the viscosity of pentosan solutions, described by Baker and co-workers (2), may explain the failure of pentosans to affect materially the behavior of doughs in the oven. These workers found that a solution which was very viscous at room temperature became almost water-thin after being warmed to 65°C. Thus, firmness imparted by pentosans would be drastically lessened as the temperature of a dough increased during baking.

The distinct modifying effects of soluble pentosans on the handling properties of reconstituted doughs were quite similar to those reported by Sandstedt, Jolitz, and Blish (10) for the small-granule fraction of

starch. Since Baker and co-workers (2) reported small-granule starch to contain up to 14% insoluble pentosans, it is possible that the effects of this starch fraction were due, in large part, to the insoluble pentosans. MacMasters and Hilbert (8) found only 4% pentosans in their preparations of small-granule starch, but it has been suggested [5] that pentosanase activity during preparation may have been partly responsible for this low value. Ofelt (9) obtained small-granule starch fractions containing approximately 8% pentosans but observed no effect of either this starch or the total water-soluble fraction on dough-handling properties. In this regard, Sandstedt and coworkers found that their small-granule starch fraction not only modified dough-handling properties but also decreased loaf volume and improved grain and texture. The divergency of all these results clearly indicates that a more extensive study is required to determine the importance of pentosans and small granule starch in the baking performance of flours of all types.

Acknowledgments

We are indebted to Wilfred Ward and Dale Smathers of this Laboratory for the ultracentrifuge examinations and to Ali Mohammad for the osmotic pressure determinations.

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[5] Personal communication from Dr. MacMasters.

THE PROTEIN, NIACIN, AND PANTOTHENIC ACID CONTENTS OF CORN INBRED LINES[1]

LORRAINE D. RODRIGUEZ, CHARLES H. HUNT, and R. M. BETHKE[2]

ABSTRACT

Thirty-nine corn inbred lines grown at Columbus, Ohio, in 1946 were analyzed for total protein, niacin, and pantothenic acid. The lines ranged from 9.9 to 17.8% protein (mean 13.1), from 12.4 to 54.1 μg. niacin (mean 22.6), and from 2.6 to 9.4 μg. pantothenic acid (mean 6.1). Tests for correlation coefficient *r* made on the assay results of the three components, each with the other, revealed no significant correlations. However, the *r* values for niacin and protein (negative) and for niacin and pantothenic acid (positive) approached the 5% level of significance, indicating that there may be some relationship between these components.

The chemical composition of the corn plant has been the subject of considerable study. Hybrids have been compared with open-pollinated varieties and attempts have been made to trace heritable characters in inbred lines and hybrids. Recently, attention has been given to vitamins, mineral elements, and amino acids of the corn grain, as well as to protein, oil, sugar, starch, and ash.

Experiment stations first produced high or low protein corn by seed selection (Hume, Champlin, and Loomis, 9; Smith, 14). Breeding high-protein corn by Mendelian methods was reported by Hayes (7).

Curtis and Earle (4) found variations attributable to heredity and/or environment in composition of grain, including protein, from 17 hybrids grown at different locations.

Sayre (13) reviewed the protein content of some open-pollinated varieties and hybrids tested at the Ohio Station during several years. Early studies showed that hybrids had a more uniform protein content than open-pollinated varieties. Open-pollinated corn grown with seven hybrids at several locations through four seasons did not always contain the lowest percent protein, but proved inferior to the hybrids in yield of protein per acre. He found that soil, season, and maturity affected protein content.

Hunt, Ditzler, and Bethke (10) have reported that while both heredity and environment affect niacin and pantothenic acid in

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hybrids, niacin is less subject to environmental influences than pantothenic acid. Further study showed the effect of specific inbred lines on both vitamins in various types of hybrids (Ditzler, Hunt, and Bethke, 5). After finding that inbred lines varied more widely than related hybrids in niacin and that hybrids high in niacin came from parents high in niacin, Gorfinkel (6) concluded that niacin in maize is a genetically inherited factor. Richey and Dawson (12) also reported wide variations in the niacin content of inbred lines. Hybrids were intermediate between the parents. These investigators believe that it would be possible to develop hybrids with 50 μg. niacin per g., but that such hybrids would be valueless unless they possessed other desirable characteristics.

A few investigators have correlated vitamin content with other components of cereal grains. The work of Burkholder, McVeigh, and Moyer (2), Mather and Barton-Wright (11), and Cameron and Teas (3) indicates a correlation between relatively high niacin and sugary-type maize endosperm. Aurand and Miller (1) reported a definite influence of heredity on the carotene and crude protein contents of single cross corn hybrids but found no correlation between the two nutrients in the corn tested. Hoffer, Alcock, and Geddes (8) found a significant positive correlation ($r = +0.326$) between thiamine and protein in 383 samples of hard red spring wheat. At this Station, Hunt and co-workers found a significant positive correlation ($r = +0.834$) between niacin and protein in 28 oats samples grown during two seasons on a 5-year rotation fertility experiment (unpublished data).

The present study was undertaken to determine whether a correlation existed in corn inbred lines between niacin and pantothenic acid and between the contents of each of these vitamins and protein.

Materials and Methods

The grain from thirty-nine corn inbred lines grown under open pollination at Columbus, Ohio, in 1946 was analyzed for total protein, niacin, and pantothenic acid. Total protein was determined by the Kjeldahl procedure. Niacin and pantothenic acid were determined microbiologically, using methods previously described (Hunt *et al.*, 1947). Results were calculated to dry matter basis. The test for correlation coefficient r was made on niacin with pantothenic acid and on protein with each of the two vitamins.

Results and Discussion

The assay results are shown in Table I. The lines ranged from 9.9 to 17.8% protein (mean 13.1), from 12.4 to 54.1 μg. niacin (mean

22.6), and from 2.6 to 9.4 μg. pantothenic acid (mean 6.1) per g. sample. The ranges of all three components were quite wide. This result agrees with the findings of Gorfinkel (6) and Richey and Dawson (12) whose tests of inbred lines showed a wide range in niacin. When the three components were correlated with each other, the values of correlation coefficient r for these three components were

TABLE I

TOTAL PROTEIN, NIACIN, AND PANTOTHENIC ACID CONTENTS OF CORN INBRED LINES GROWN AT COLUMBUS, OHIO, IN 1946

(Dry matter basis)

Inbred line	Total protein %	Niacin mcg./g.	Pantothenic acid mcg./g.
Ind. WF9	12.1	25.8	8.2
CI.4–8	14.4	18.0	5.1
Ind. Tr	11.9	27.0	5.1
W23	9.9	33.0	6.7
CI.7	13.4	24.7	8.1
CI.187–2	12.7	18.2	5.8
H5	14.9	16.4	6.0
H7	17.8	27.9	5.9
Ia.1205	12.7	23.7	7.1
K4	14.4	21.4	9.0
K155	11.8	20.6	4.7
K166	12.8	24.0	7.6
Ia.L289	12.9	20.1	4.4
Ia.L317	13.8	12.4	4.1
Ill. M14	12.7	24.4	6.6
T8	12.3	19.1	6.1
Ia. Os 420	13.7	23.6	8.1
Ia. Os 426	13.4	18.7	4.2
Ill. A	14.7	23.7	5.8
Ill. Hy	11.1	15.8	3.3
Ind. 38–11	15.0	20.6	6.2
Ia. P8	13.2	17.8	5.8
Kys	15.7	25.8	7.2
Oh02	12.6	32.0	6.9
Oh04	13.0	24.4	6.4
Oh07	12.0	27.0	5.8
Oh7A	11.3	54.1	6.9
Oh26	13.6	15.8	6.6
Oh28	11.6	43.6	5.4
Oh33	12.6	13.3	4.6
Oh40B	12.9	13.6	7.3
Oh41	12.1	15.2	5.4
Oh51	11.0	16.8	6.2
Oh51A	11.3	23.0	5.5
Oh56	13.2	20.1	4.7
Oh56A	13.9	19.6	9.4
Oh65	14.6	13.2	2.6
Oh84	12.7	23.6	6.2
Oh93	14.0	22.4	6.3
Mean	13.1	22.6	6.1
Minimum	9.9	12.4	2.6
Maximum	17.8	54.1	9.4

as follows: for protein with niacin, −0.249; for protein with pantothenic acid, +0.086; for niacin with pantothenic acid, +0.285. None of the values for r was significant for 39 pairs. However, the r values for protein with niacin and for niacin with pantothenic acid approach significance (r = approximately .31 at 5% level) and indicate that there is probably some relationship between the components compared.

Acknowledgment

The authors are indebted to J. D. Sayre, Department of Agronomy, Ohio Agricultural Experiment Station, in cooperation with the United States Department of Agriculture, for supplying the samples analyzed.

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COMMUNICATIONS TO THE EDITOR

The Lever System of the Baker Compressimeter [1]

SIR:

The Baker Compressimeter, since it was first reported by Platt,[2] has been used by a number of workers to follow the change in firmness or compressibility of bakery products during the progress of staling. Platt in his original paper stated, "When the plunger is depressed, the amount of the depression is multiplied 10 times and is read direct in millimeters on scale D." However, he did not mention any factor for converting force scale readings into actual depressing force.

Recently, Favor and Johnston [3] reported the use of the Baker instrument in a study of the effect of polyoxyethylene monostearate on the staling of bread. These authors stated that "The stress in grams read from the scale on the instrument was multiplied by 10 to show the actual stress applied by the lever system to the section of bread crumb, and to secure better correlation with similar readings taken from other types of compressibility testers."

Other workers [4] have made similar statements, but attempts to demonstrate a correlation between the Baker Compressimeter and the Universal Penetrometer in this laboratory indicated that some factor other than 10 was involved.

To clarify this matter all the levers on the Baker instrument, with the exception of the one bearing the stress indicator, were immobilized with Scotch tape. By hanging analytical weights at the point where force is normally applied, it was found that with only a slight error, due perhaps to lack of linearity in the spring, the force scale values in grams equalled the force applied at this point.

The Baker Compressimeter was dismantled and the various levers were measured carefully with a steel scale. The results are shown in Fig. 1.

From these measurements it was possible to validate Platt's statement that the amount of depression is read directly from the instrument scale. The lever system, HG/DG, produces a tenfold

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[1] These observations were made incidental to the course of an investigation supported by the United States Department of Agriculture under the Research and Marketing Act, Contract No. A-1S-30909. The conclusions contained in this report are those of the authors and are not to be construed as necessarily reflecting the views or indorsement of the Department of Agriculture.

[2] Platt, W. and Powers, R. Compressibility of bread crumb. Cereal Chem. 17: 601–621 (1940).

[3] Favor, H. H., and Johnston, N. F. Effect of polyoxyethylene stearate on the crumb softness of bread. Cereal Chem. 24: 346–355 (1947).

[4] Noznick, P. P., and Geddes, W. F. Application of the Baker Compressimeter to cake studies. Cereal Chem. 20: 463–477 (1943).

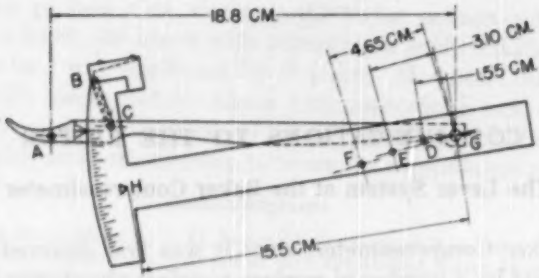

Fig. 1. Lever system of the Baker Compressimeter.

magnification of the depression, but the true depression is read in millimeters from the scale of the instrument. There is a small error resulting from angular displacement which may be ignored.

An examination of the levers involved in the force system revealed that for Plunger Position D the mechanical advantage is as follows:

$$\text{Mechanical Advantage:} = \frac{AG}{CG} \times \frac{CG}{BG} \times \frac{BG}{DG} = \frac{AG}{DG}.$$

From this observation and the lever measurements it was possible to calculate the theoretical conversion factor for the force scale for each of the three plunger positions. The following formula was employed:

$$f_A = f' \cdot \frac{d_A}{d'}$$

where:

f_A = force applied to the sample by the plunger.

f' = force applied to the lever at A and transferred to the plunger at B by a spring. This was determined to be the scale reading.

d_A = length of the lever to which force is applied by a motor from the fulcrum, G to A.

d' = length of the lever from G to the plunger where force is applied to the sample, D, E or F.

$\frac{d_A}{d'}$ = mechanical advantage of the system.

The results are as follows:

	Plunger Position		
	D	E	F
d_A, cm.	18.8	18.8	18.8
d', cm.	1.55	3.10	4.65
Mech. Adv.	12.1	6.06	4.04

Having been assured that the Baker Compressimeter is a standardized machine [5] and that the one studied was a stock model, it would appear that the true factor to use in converting the force scale to actual force applied at the first plunger position (*D*) is 12.1 rather than 10.

By assuming that the lever-free Penetrometer provided accurate force-depression values on sponge rubber blocks, and by correlating these with Baker readings on the same blocks, it has been possible to demonstrate that the theoretical constants obtained are correct. The experimentally determined constants had an average deviation from the theoretical of 1.3% or less.

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October 11, 1949

The Amino Acid Composition of Whole Wheat in Relation to its Protein Content

DEAR SIR:

During some recent studies in these laboratories the essential amino acid composition of 4 samples of different varieties of whole wheat has been determined by microbiological assay. The results suggest that the fraction of the total (Kjeldahl) nitrogen contributed by several of the amino acids may not be wholly independent of the nitrogen content of the sample, tending to be higher in samples of lower nitrogen content. This was most marked with arginine, lysine and valine, figures for which are given below. No such tendency was noted with phenylalanine, histidine, tryptophane or tyrosine. None of the amino acids so far studied (the ten "essential" amino acids and tyrosine) showed the reverse tendency.

	Nitrogen	Arginine*	Lysine*	Valine*
	%	%	%	%
White English Wheat	1.58	10.2	4.12	3.56
N. S. W. Australian	1.81	9.08	3.81	3.44
New Crop Plate	2.27	8.94	3.46	3.32
Tough No. 2 Manitoban	2.43	8.75	3.39	3.15

* Amino acid nitrogen as per cent of total nitrogen.

We have not so far determined the non-protein nitrogen content of our samples; variations therein might, of course, explain the results observed. Alternatively, it may be that the samples contain different proportions of the individual wheat proteins.

[5] Personal communication, Meade Harris, Wallace and Tiernan Company, Inc., Chicago, Illinois.

Some data recently published by McElroy *et al.* (1), in which the essential amino acids in nine samples of one variety each of wheat, barley and oats were compared, show some interesting points of similarity. Their figures show that there was a within-species variation of amino acid content which, in the case of wheat, was most evident for lysine, arginine, valine, isoleucine and histidine. Furthermore, as they point out, it appears that the fraction of the total nitrogen contributed by the nitrogen of lysine may decrease as the total N increases —a tendency that, their figures suggest, may apply to certain other amino acids also.

Thus there appears to be accumulating evidence that the crude protein of wheat samples lowest in nitrogen may contain rather higher proportions of several of the amino acids, suggesting that there are qualitative, as well as quantitative, differences in protein content.

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October 28, 1949

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1. MCELROY, L. W., CLANDININ, D. R., LOBAY, W., and PETHYBRIDGE, S. I. Nine essential amino acids in pure varieties of wheat. J. Nutrition **37**: 329–336 (1949).

BOOK REVIEWS

Outlines of Biochemistry. By Ross Aiken Gortner. Third Edition edited by Ross Aiken Gortner, Jr. and Willis Alway Gortner. 1078 pp. John Wiley & Sons, Inc., New York and Chapman & Hall, Ltd. London. Price $7.50.

Outlines of Biochemistry has long been regarded as a classic in its field. The appearance of this revised edition will be welcomed by biochemists everywhere. It was made possible through the efforts of a number of authorities on various phases of biochemistry, nearly all of whom were former students or colleagues of the late chief of the Division of Agricultural Biochemistry at the University of Minnesota.

While many advances have been made in the eleven years since the last revision, these have been incorporated without greatly altering the general form and size of the book. Subject matter is divided into six sections dealing with colloids, proteins, carbohydrates and related substances, lipids and essential oils, plant pigments and biochemical regulators. Most of the chapter headings are the same as formerly, but some have been combined, some completely rewritten, and three new chapters included.

The section on colloids has been greatly condensed and relatively little new material added. All the other sections have been expanded.

In the protein section a new chapter on protein denaturation has been added. The chapter on protein analysis now includes descriptions of ion exchange and chromatographic separation methods for separation of amino acid mixtures and microbiological techniques for amino acid analyses.

The carbohydrate section has been almost completely rewritten. The subject is developed in an excellent fashion and includes many citations of recent literature. Errors found in some structural formulas in the previous editions have been corrected. A new chapter on carbohydrate metabolism, a field in which remarkable progress has been made in the last few years, has been added.

Lipid metabolism is the subject of a new chapter in the lipid section. Recent findings on the mechanism and inhibition of fat oxidation are also reviewed.

Extensive revisions have been made in the last two sections to present up-to-date information on the chemistry of plant pigments, vitamins, hormones, and enzymes.

Contributors to the revision were Drs. S. I. Aronovsky, P. D. Boyer, D. R. Briggs, H. B. Bull, G. O. Burr, W. F. Geddes, R. A. Gortner, Jr., W. A. Gortner, H. O. Halvorson, W. M. Sandstrom, T. J. Schoch, and J. J. Willaman.

The third edition upholds the high standards set by the original author. It should be a valuable aid to every cereal chemist as well as to others working with biological materials.

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Nutritional Data. Published and distributed gratis by the H. J. Heinz Co., P. O. Box 57, Pittsburgh, Pa.

As a successor to "Nutritional Charts," "Nutritional Data" will be welcomed by the large number of people working in the medical and biological professions, and by nutritionists and dietitians who have valued the previous 12 editions of "Nutritional Charts" as a ready source of reference. "Nutritional Data" is a revision and expansion of its predecessor which contains much added material and retains many of the valuable features of the original publication. The subject matter, treated mostly in tabular form, is divided essentially into the following ten sections: Vitamins, The Essential Elements, Proteins and Amino Acids, the Availability of Nutrients, Signs and Symptoms of Malnutrition, the Metabolism and Action of Foods, Human Dietary Requirements, Planning Diets for Good Nutrition, Tables of Food Composition and Nutritive Value, Nutritional Activities of H. J. Heinz Co., Suggestions for Further Reading. The section devoted to tables of food composition and nutritive values forms the backbone of this publication. This section will be particularly

valuable to dietitians, and it constitutes a convenient source of reference for others. Compared to previously published tables of food composition in "Nutritional Charts," these new tables have been revised to conform with the latest analytical data available. That such a revision is desirable is indicated by the fact that the analyses of what might be considered well-known staple foods, such as whole-wheat flour, oatmeal and peanut butter, given in the present issue are somewhat different from those previously listed. The expression of the mineral content of foods in terms of grams or milligrams per 100 grams of edible portion rather than in terms of percent is a distinct improvement. The columns giving the alkaline or acid effect of foods which were previously incorporated in the tables of food composition have been deleted. The descriptive and factual material presented in "Nutritional Data" is in general quite accurate and reliable. Perhaps it would be desirable if in the section on vitamins the deficiency signs and symptoms which are listed were more clearly identified with the species involved, particularly where specific symptoms have not been identified in human beings. While an effort in this direction has been made, the differentiation between symptomology in different species is not as clear-cut as might be desired. A few inaccuracies have been found in the text, but in general, they are not of a serious nature. For example, the statement made on page 31 to the effect that copper is necessary for conversion of iron into hemoglobin is not as yet supported by experimental evidence, nor should pantothenyl alcohol which is listed on page 45 as a pantothenic acid antagonist be classified in this manner inasmuch as it is readily available to human beings and oxidized by them to pantothenic acid.

The reviewer feels certain that there will be a great demand for "Nutritional Data" and that it will be a valuable reference to all the people interested in the field of nutrition. The sponsors of this publication and the editorial staff are making a fine contribution to better nutrition through the compilation and distribution of "Nutritional Data."

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Cereal Chemistry

EDITORIAL POLICY

Cereal Chemistry publishes scientific papers dealing with raw materials, processes, or products of the cereal industries, or with analytical procedures, technological tests, or fundamental research, related thereto. Papers must be based on original investigations, not previously described elsewhere, which make a definite contribution to existing knowledge.

Cereal Chemistry gives preference to suitable papers presented at the Annual Meeting of the American Association of Cereal Chemists, or submitted directly by members of the Association. When space permits, papers are accepted from other scientists throughout the world.

The papers must be written in English and must be clear, concise, and styled for *Cereal Chemistry*.

Manuscripts for publication should be sent to the Editor in Chief. Advertising rates may be secured from and subscriptions placed with the Managing Editor, University Farm, St. Paul 1, Minnesota. Subscription rates, $7.50 per year. Foreign postage, 50 cents extra. Single copies, $1.50; foreign, $1.60.

Entered as second-class matter March 3, 1932, at the post office at Lancaster, Pa., under the Act of August 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of October 3, 1917, authorized February 16, 1924.

SUGGESTIONS TO AUTHORS

General. From January 1, 1948, an abstract will be printed at the beginning of each paper instead of a summary at the end, references will be numbered to provide the option of citing by number only, and date of receipt, author's connections, etc., will be shown in footnotes. Except on these points, authors will find the last volume of *Cereal Chemistry* a useful guide to acceptable arrangements and styling of papers. "On Writing Scientific Papers for Cereal Chemistry" (*Trans. Am. Assoc. Cereal Chem.* 6: 1–22. 1948) amplifies the following notes.

Authors should submit two copies of the manuscript, typed double spaced with wide margins on 8½ by 11 inch white paper, and all original drawings or photographs for figures. If possible, one set of photographs of figures should also be submitted. Originals can then be held to prevent damage, and the photographs can be sent to reviewers.

Titles and Footnotes. Titles should be specific, but should be kept short by deleting unnecessary words. The title footnote shows "Manuscript received . . ." and the name and address of the author's institution. Author footnotes, showing position and connections, are desirable although not obligatory.

Abstract. A concise abstract of about 200 words follows title and authors. It should state the principal results and conclusions, and should contain, largely by inference, adequate information on the scope and design of the investigation.

Literature. In general, only recent papers need be listed, and these can often be cited more advantageously throughout the text than in the introduction. Long introductory reviews should be avoided, especially when a recent review in another paper or in a monograph can be cited instead.

References are arranged and numbered in alphabetical order of authors' names and show author, title, journal, volume, first and last pages, and year. The list is given at the end of the paper. Reference numbers must invariably be cited in the text, but authors' names and year may be cited also. Abbreviations for the names of journals follow the list given in *Chemical Abstracts* 40: I–CCIX. 1946.

Organization. The standard organization involves main sections for abstract, introduction, materials, methods, results, discussion, acknowledgments, and literature cited. Alternately, a group of related studies, each made with different materials or methods, may require a separate section for each study, with subsections for materials and methods, and for results, under each section. Center headings are used for main sections and italicized run-in headings for subsections, and headings should be restricted to these two types only.

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Tables should be typed on separate pages at the end of the manuscript, and their position should be indicated to the printer by typing "(TABLE I)" in the appropriate place between lines of the text. (Figures are treated in the same way.)

Figures. If possible, all line drawings should be made by a competent draftsman. Traditional layouts should be followed: the horizontal axis should be used for the independent variable; curves should be drawn heaviest, axes or frame intermediate, and the grid lines lightest; and experimental points should be shown. Labels are preferable to legends. Authors should avoid identification in cut-lines to be printed below the figure, especially if symbols are used that cannot readily be set in type.

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All original figures should be submitted with one set of photographic reproductions for reviewers, and each item should be identified by lightly writing number, author, and title on the back. Cut-lines (legends) should be typed on a separate sheet at the end of the manuscript. "Preparation of Illustrations and Tables" (*Trans. Am. Assoc. Cereal Chem.* 3: 69–104. 1945) amplifies these notes.

Text. Clarity and conciseness are the prime essentials of a good scientific style. Proper grouping of related information and thoughts within paragraphs, selection of logical sequences for paragraphs and for sentences within paragraphs, and a skillful use of headings and topic sentences are the greatest aids to clarity. Clear phrasing is simplified by writing short sentences, using direct statements and active verbs, and preferring the concrete to the abstract, the specific to the general, and the definite to the vague. Trite circumlocutions and useless modifiers are the main causes of verbosity; they should be removed by repeated editing of drafts.

Editorial Style A.A.C.C. publications are edited in accordance with *A Manual of Style*, University of Chicago Press, and *Webster's Dictionary*. A few points which authors often treat wrongly are listed below:

Use names, not formulas, for text references to chemical compounds. Use plural verbs with quantities (6.9 g. were). Figures are used before unit abbreviations (3 ml.), and % rather than "per cent" is used following figures. All units are abbreviated and followed by periods, except units of time, which are spelled out. Repeat the degree sign (5°–10° C.). Place 0 before the decimal point for correlation coefficients ($r = 0.95$). Use * to mark statistics that exceed the 5% level and ** for those that exceed the 1% level; footnotes explaining this convention are no longer required. Type fractions on one line if possible, e.g., $A/(B + C)$. Use lower case for farinograph, mixogram, etc., unless used with a proper name, i.e., Brabender Farinograph. When in doubt about a point that occurs frequently, consult the Style Manual or the Dictionary.

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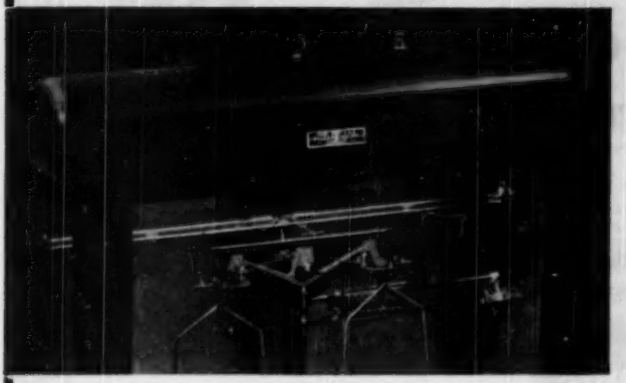

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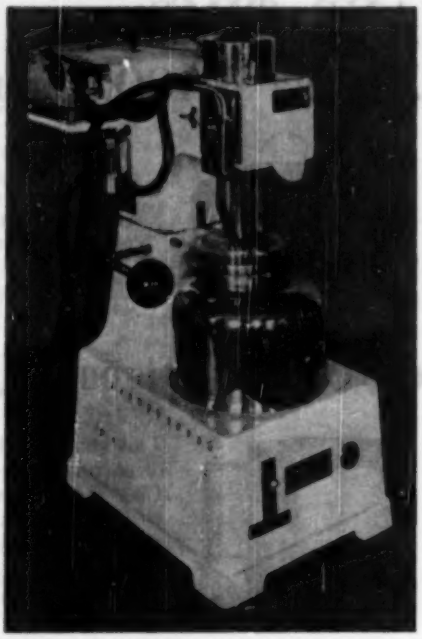

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